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THE CONTROL OF HUMAN FERTILITY

by

SIR SOLLY ZUCKERMAN

Sir Solly Zuckerman, F.R.S., Professor of Anatomy at the University of Birmingham, is Deputy Chairman of the U.K. Advisory Council on Scientific Policy, and Chairman of the Natural Resources (Technical) Committee.

INTRODUCTION

With the very high rates of population growth which now prevail in many parts of the world, particularly in Asia, the control of human fertility has become one of the most urgent and most widely discussed problems of the day. But it is neither a new nor an isolated problem. The mysteries of reproduction belong to the very beginnings of man's wonderings about himself; and to the scholar, the question of human fertility is merely part of the wider problem of how population growth is related to the development of physical resources and to social and economic evolution.

No one knows exactly when the kind of creature we recognize as man sprang into existence. It may have been a half-million years ago; it may have occurred even further back in the geological epoch called the pleistocene. During all but the most recent part of this long period, our palaeolithic forebears lived in small, scattered, nomadic parties, and existed exclusively by hunting and fishing, and on the fruits and plants provided by nature. The emergence of the neolithic civilization, when man became a food producer, is a relatively recent phenomenon which took place less than 20,000 years ago. It constituted the first major advance in the evolution of the kind of social pattern and the type of economic system in which we are now organized.

The neolithic revolution was based upon the twin discoveries of crop cultivation and animal husbandry. Both innovations necessitated the establishment of permanent settlements, and the neolithic civilization automatically became associated with an increase in the size of the individual community. The making of pots, which may have been discovered in the last phases of man's earlier food-gathering existence, became an essential part of neolithic life, and marked the fact that agricultural communities could preserve and store food surpluses not only for future consumption, but also for purposes of trade. Then came the invention of writing and the use of metals, and the further specialization of labour and function within the com-

munity—a process which had almost certainly begun in the first neolithic settlements. All these developments resulted in an even greater enlargement of what has been called 'the unit of cohabitation of human societies'. A metal-using civilization also meant more trade, as well as colonization and the multiplication of new settlements. And this in turn led to the still further growth of population.

But apart from these effects, the evolution of a settled form of life also emancipated man from the rigid controls of nature which determine the numbers of animals in the wild. When food is scarce, wild animals have fewer young, and fewer of those that are born live to reach sexual maturity. The more adults there are in times of scarcity, the fewer survive to enjoy the full span of reproductive life. And the more crowded a community becomes, the more readily will communicable diseases, such as parasitic infestations, spread. These are examples of the so-called 'density-dependent' controls, which regulate both the rates at which species reproduce and the interaction of the population cycles of the different kinds of creature that prey on each other. In so far as animals are always potentially pressing on their means of subsistence, 'density-dependent' factors also act as a powerful spur to dispersal. Dispersal leads to the separation of inbreeding groups, and these in turn constitute a social condition which is potent in evoking evolutionary change. It was almost certainly in the long period during which palaeolithic man lived in isolated groups—groups which did not mix their genes with those of other groups—that the main subdivisions of the human race as they exist today evolved. The emergence of the neolithic and later civilizations, of which trade has from the start been a characteristic feature, not only began the process of man's emancipation from a state of nature; it also initiated those trends in human society that were the reverse of the centrifugal forces which in the non-human world as well as in the palaeolithic human world played so powerful a part in the emergence of new varieties and new species.

THE MALTHUSIAN PRINCIPLE

Until little more than two hundred years ago, when the industrial phase of civilization began, such limits as there were to the growth of a human community were usually set by its capacity to produce and distribute food within the area in which it lived or over which it held sway—as is still the case in peasant societies today. It was the belief that this was some kind of immutable law which led Malthus, at the turn of the eighteenth century, to enunciate his celebrated proposition that the numbers of any human community were always bound to oscillate around some maximum set by its known means of subsistence. Malthus held that population invariably increases 'where the

means of subsistence increase', and that it would continue to do so unless prevented by the very powerful positive checks of vice, misery and war, or by the negative check of 'moral restraint', by which Malthus essentially meant delayed marriage.

Malthus's economic and demographic views have never ceased, and will probably never cease, to be the subject of academic and political debate. A more practical consequence of the vigorous controversy he started was the emergence of the modern birth control movement. Equally, because events falsified his worst prognostications about the consequences of any significant increase in the population of Great Britain, the name of Malthus has provided a rallying point for all those who are opposed, for any reason, to the idea that deliberate steps should ever be taken to limit population growth.

Malthus feared that an increase in the national product would stimulate a greater relative increase in population, and that in consequence the average *per capita* income would decline. In fact, it was the reverse which occurred in Great Britain. The increasing pace of industrialization in the nineteenth century, and a rising volume of food imports, resulted not only in a phenomenal growth of population, but also in an increase in the average standard of living. As the nineteenth century approached its close, there were many who could see little reason why this favourable process should not continue for ever—at any rate, in England. On the other hand, the concept of an ever-rising real income *per capita* did not obscure the fact that the national product was being shared far from equally within the population.

In the first half of the nineteenth century, the family pattern of the poorer classes of the community had become adjusted to an ever-mounting demand for labour; for more children meant more money for all. But as the years passed and one governmental reform after another restricted the use of children in industry and improved the level of general education, the prolificacy of the poor only added to the burden they had to bear. In due course, smaller families—the inevitable adaptation to the new conditions—became the pattern of the day.

So far as available statistics give any indication, there were marked fertility differentials between social classes even before this time. As a rule, the more well-to-do had fewer children, while the numerous broods of the poor suffered from a higher mortality. Fertility differentials presumably also existed between the rural and urban populations, for, with few exceptions, it has always been found that reproductive rates vary inversely with the degree of urbanization as well as with the level of literacy. Thus fertility rates are, in general, higher amongst agricultural and non-skilled workers than amongst any other members of the working population, the lowest rates applying as a rule to the professional classes. On the other hand, there are indications that within equivalent occupational groups the more wealthy sometimes have higher fertility rates.

The fact that fertility rates vary in this way between social groups, and that they can also vary for a population as a whole, is an indication that there are always means of limiting reproductive capacity. The indirect part which Malthus played in spreading the knowledge of these means was considerable. Although he himself believed that moral restraint constituted the only acceptable way of limiting the growth of population, others, seized with the force of his economic and demographic arguments, decided that this was not enough.

The first to enter the fray was Francis Place, who is described by Dr. Norman Himes[1] as a 'self-taught working man who rose to prominence in English political life through sheer dint of heroic effort'. In 1822, Place published a book entitled *Illustrations and Proofs of the Principle of Population*, in which, in place of late marriage, he advocated the use of various contraceptive measures as a means of limiting family size. He also started disseminating handbills on the subject, stressing not only the wisdom of having fewer children in order to alleviate poverty, but also the desirability of decreasing the ill-health which so often follows excessive child-bearing. Place was followed by others, of whom one of the more important, Dr. Charles Knowlton, a New England physician, published in 1832 a tract on contraception called *Fruits of Philosophy*. This was reprinted in London in 1834. It sold at a modest rate for some forty years until it suddenly became very widely known as a result of the conviction of one Henry Cooke of Bristol, who was alleged to have republished the pamphlet as an obscene work. Charles Bradlaugh and Annie Besant, two leaders of the Free Thought Movement of the time, held that the conditions of the poor could not be improved unless fewer children were born. They therefore decided to settle the legality of sale of Knowlton's work by re-issuing the pamphlet, and informed the police of their intention to do so. The trials which followed their arrest in 1877 attracted considerable attention and directed a blaze of publicity to the facts of fertility control. With the loss of the Crown's case, the right to publish information about birth control was vindicated in England. The immediate social effects were remarkable: the national birth rate, which had risen from 32.6 per 1,000 in 1850 to 35.4 in the year of the trial, fell below 30 by the turn of the century, and to less than 20 some twenty years later. Today it stands at about 16 per 1,000.

CONTRACEPTION THROUGHOUT HISTORY

Apart from those measures for limiting fertility which can be properly described under the heading of moral restraint—that is to say, fewer marriages or deferred marriages—the contraceptive methods which the nineteenth-

1. Norman E. Himes, *Medical History of Contraception*, Baltimore, 1936.

century English publicists were advocating differed scarcely at all from various traditional practices that had been known for thousands of years. Artificial methods of birth control of varying efficiency are part of the culture of practically every pre-literate community that has ever been studied, and the records show that they also had a place in the civilizations of ancient Egypt, Greece and Rome. In Egyptian literature the earliest reference to a medical prescription for preventing conception occurs in the Petri Papyrus, which dates from the reign of Amenhat III of the Twelfth Dynasty, about the period 1850 B.C. The Chinese had at least as ancient a knowledge of methods of limiting family size; and references to contraceptive practices also occur in early Islamic and Judaic literature.

The term 'fertility control' is as a rule used widely to include practices like abortion, infanticide and incomplete intercourse, as well as artificial methods of obviating the chance that a viable spermatozoon from the male will fuse with a viable ovum from the female. 'The most brilliant and original account of contraceptive techniques' written prior to the nineteenth century was that of Soranus of Ephesus (A.D. 98-138), who had studied in Alexandria and then practised in Rome.[1] Soranus distinguished clearly between rational and magical methods, and between contraceptives proper and abortifacients. One of the 'magical' contraceptive measures to which he refers is the wearing of amulets; another is the belief that 'water from the fire bucket of the smith, when drunk continuously after every menstrual period, causes sterility'. This prescription, it seems, was until very recently still accepted by peasants in remote regions of Europe as a contraceptive practice.

In the main, Soranus advocated various materials which could be used to form a physical barrier between the uterus and the vaginal lumen, the techniques he mentions being apparently the same in kind as those which are recorded in the literature of other early cultures. He also refers to various solutions that were believed to have spermicidal properties when applied locally, and records the ancient belief that the most fruitful periods of the menstrual cycle are directly before and after menstruation. This incorrect view prevailed until some twenty-five years ago.

There have been only three major practical developments in contraceptive practice since Soranus' day. The first derived from the discovery, in the middle of the nineteenth century, of the vulcanizing of rubber. This industrial process, and the more recent introduction of latex rubber, made possible the manufacture of physical barriers to the deposition of spermatozoa within the female genital tract or to their passage from the vaginal to the uterine lumen —barriers which were far more effective than those previously known. The second was the development of spermicidal substances of scientifically assured potency to take the place of the crude local treatments which were in use

1. See Himes, op. cit., p. 88.

until relatively recently. The third derived from a proper understanding of the facts of reproductive physiology, in particular, from a scientific appreciation of the timing of ovulation and of the length of time ova and spermatozoa remain viable within the genital tract.

During each menstrual cycle the ovaries usually liberate only a single ovum, the process of ovulation occurring at some moment about midway between the onset of successive phases of the menstrual bleeding which marks the breakdown of the lining membrane of the uterus. Since ova and spermatozoa are viable for only a day or two, the total period in a month in which any woman has a maximum chance of conceiving is little more than about three days. The difficulty of utilizing this fact in order to control human fertility derives from the variability in time of the phenomena concerned.

Thus, although the interval between successive phases of uterine bleeding usually lasts about four weeks, the length of the cycle varies greatly between different women, and in the same woman from time to time. Furthermore, the most variable part of the cycle is its pre-ovulatory phase, the period after ovulation being much more constant and about two weeks in duration. Because it is not the other way about, it is impossible to predict with accuracy how many days after the onset of bleeding ovulation is going to occur. In order to estimate the time limits within which it might happen in a given cycle, it is first necessary to have records of the duration of cycles over a fairly lengthy preceding period. The likely minimum and maximum lengths of the whole cycle having been determined, it is then possible to calculate the probable period after the onset of a phase of uterine bleeding within which ovulation might occur, on the assumption that ovulation generally takes place about fourteen days before the end of the cycle. The time of ovulation in any particular cycle cannot be predicted with greater exactitude than this, unless the individual concerned also makes use of the fact that the process of ovulation is usually associated with a slight rise in body temperature, and takes careful and precise daily measurements.

Useful information about the duration of the fertile period in women has been collected by physicians who specialize in the technique of artificial or 'therapeutic' insemination. In one extensive series of records,[1] the length of the menstrual cycle varied from 20 to 38 days, and the period within which inseminations succeeded in bringing about pregnancy ranged from the tenth to the twentieth day after the start of the cycle, the most fertile period being the four days from day 11 to day 14. The general conclusion of this study was that ovulation usually occurs about two days before the mid-cycle day, and that the potential fertile period lasts eight days including the four days previous to and the three days after the mid-cycle day.

1. *Proceedings of the Fifth International Conference on Planned Parenthood*, Tokyo, 1955. London, International Planned Parenthood Federation.

In recent years the countries of the West have succeeded in controlling their reproductive rates by utilizing both this kind of knowledge and the various modern contraceptive techniques that are now available. However, every one of these methods leaves much to be desired. They are far from infallible, their rate of failure being in inverse ratio to the standards of living and levels of literacy. Since there are no techniques for limiting fertility other than those now being practised in the West, it is obvious that their shortcomings will be even more conspicuous in the environment of the illiterate and impoverished communities of the underdeveloped territories of the world.

FERTILITY CONTROL IN THE OVERPOPULATED COUNTRIES

India is perhaps the most obvious case in point. Here we have a country with a population of nearly 400 million and an average standard of living which is one of the lowest in the world. The Government and the literate public appreciate that the present rate of reproduction, about 1.4 per cent per annum, jeopardizes the considerable efforts that are now being made both to improve and extend social services such as education and public health, and to encourage industrialization and other measures aimed at raising the level of the country's economic activity. Not long after India assumed full responsibility for her own political and social destiny, an official campaign was, therefore, begun to spread knowledge of birth control. In spite of valiant efforts, the results so far achieved are trivial in relation to the scale of the problem and have hardly begun to make any impact on the general situation. One or two costly and highly publicized experiments designed to spread a knowledge of the so-called rhythm method of control—which is based on the idea that fertility can be controlled by regulating sexual behaviour in accordance with estimates of the likely time of ovulation—proved conspicuous failures, for the simple reason that the individuals concerned were neither literate enough to appreciate what needed to be done, nor impressed with the sense that anything needed to be done at all.

The vast mass of India's population are illiterate villagers engaged in peasant farming, and even the inhabitants of most of the larger towns, such as Calcutta, live in squalid crowded conditions. As one Indian demographer has put it, to an Indian villager the cost of an additional baby is less than the cost of a contraceptive. Even if this were not the case, the prevailing social conditions, such as the low standards of housing and the paucity of educational and medical services, make it almost unthinkable that Western methods of fertility control could be spread fast enough to stem the growth of population over the next decade or so. The result is that, while India's gross national product is increasing every year, the numbers of people who are redundant to

India's real labour requirements are increasing at an even greater rate. The lack of efficient methods of limiting fertility can, therefore, only add to the problems with which India's political leaders have to contend. And these problems are likely to become even more acute as mortality rates continue their downward trend in consequence of public health measures directed to the elimination of the malaria-carrying mosquito and to the suppression of communicable diseases such as smallpox and cholera. The figures speak only too plainly. In the decade 1911-20 the death rate was about 50 per 1,000. Today it has fallen to almost half that figure, whereas the birth rate is still about 40, only some ten points less than the maximum ever estimated for the country. It seems almost inevitable that the death rate will continue to fall faster than the birth rate, and that the rate of population growth will, in consequence, increase well beyond its present level of about 1.4 per cent.

This is precisely what happened to India's smaller neighbour, Ceylon, where a prevailing sense of prosperity and well-being tends to obscure the overriding fact that the population, partly because of a lack of any real desire to limit the size of families, and partly because of a lack of any effective knowledge of how to do so, is increasing at a phenomenal rate. At the beginning of the 1920's, Ceylon's birth and death rates were about 39 per 1,000 and 29 per 1,000 respectively, that is, about the same as India's are today. By 1945 the death-rate had fallen to 22, with the birth rate still remaining at about 40. D.D.T. then became available and, as a result, malaria, which had previously ravaged the island, was brought under control—with dramatic results. In 1946 the death rate was 20.3. The following year it ras 14.3 and today it stands at about 11. But the birth rate is still running at about the same figure as in the 1920's, with the consequence that Ceylon's population is now multiplying at a rate of about 2.6 per cent a year. This has meant an increase in population from a total of 6.5 million in 1945 to one of about 9 million today. The resulting strain on the economy has been considerable, and is likely to become more intense in the next few years because of the recent decline in Ceylon's agricultural and industrial production and the fall in her gross national product. It would not be surprising if the Government of Ceylon were now to give much more than the lukewarm support it has so far accorded to a birth control movement, the progress of which appears to have lagged even behind the corresponding Indian campaign.

Regarded purely in terms of rate of population growth, the situation is not as bad in Japan as it is either in Ceylon or in India; but it is nevertheless extremely serious. Before Japan embarked on a policy of industrialization in 1870, her population had been kept in balance over a considerable period of time at a level of about 30 million, largely through the practices of abortion and infanticide. In 1939, after seventy years of intense drive in the industrial,

agricultural and military fields, the figure had risen to 70 million. All this time the standard of living was also rising, or at least not falling, largely owing to extremely successful efforts to improve the efficiency of agriculture, and in particular of the cultivation of rice. In 1945, at the conclusion of a war in which she had suffered a considerable loss of life both in the civilian and military sectors, Japan nevertheless had a population of about two millions more than it had had at the start of the war. Since then some twenty millions more have been added, and on the most conservative estimate it seems more than likely that the figure of 100 million will be reached by or before 1965. The actual rate of increase is about 1.3 per cent, the birth rate running at about 21 per 1,000 and the death rate at the extremely low level of 8.2 per 1,000.

All possible encouragement is given by the Government and various public bodies to the spreading of knowledge of every method of birth control. But contraceptive techniques are still insufficiently known among Japan's considerable rural and agricultural population, and both rural and urban couples rely extensively on the legalized practice of abortion to limit the size of their families. There is even some indirect evidence, deriving from the very high sex-ratio in favour of males in large families, that the practice of infanticide may not have quite died out in remote districts.[1] In any case, the prevalence of abortion as a background to a national campaign to spread a knowledge of birth control is a grim sign of the determination with which the whole Japanese population regards the threat of too high a reproductive rate to their future welfare, all the more so as the country's economic potentialities are already stretched almost to the limit.

Abortion, we are told, has also now been legalized in China, whose 600 million people are now multiplying at a rate which is reliably estimated at over 2 per cent per annum. It is only in the past two years that China has abandoned the attitude to birth control according to which the inhibition of the growth of population is an unnecessary measure that has to be resorted to by capitalist countries simply because of their inability to control the rate of growth of production. Like Japan, China now appears to be publicizing every known method for preventing conception, including sterilization. How rapidly she will be able to reduce the current rate of growth of her population remains to be seen.

The efforts now being made by countries like Egypt to improve their standards of living and to raise their levels of economic activity are also jeopardized by too rapid a growth of population, and here, too, governmental authority has been given to measures designed to spread a knowledge of contraception

1. Harno Mizushima, *World Population Conference*, 1954, Vol. 1, p. 961.

amongst the people. But in Egypt, as in India, the major difficulties with which the authorities have to contend are, first, the failure of a predominantly peasant population to appreciate the need to limit the size of their families; second, illiteracy and squalor; and third, resignation to a state of poverty which is all that has ever been known. Real *per capita* income in Egypt today is lower than it was 30 years ago.

But many underdeveloped countries in which population is growing very fast have not even reached the stage where governments are prepared to tolerate, let alone promote, campaigns for the control of fertility. This applies, for example, to most of the islands of the Caribbean, where prevailing rates of population growth, which vary between about 2 per cent and 3 per cent, are completely out of balance with current rates of economic growth. Only in the island of Barbados, which has a population of 220,000 and little prospect of increasing the level of economic output by more than about 0.5 per cent a year, is the Government openly encouraging by every means at its disposal a campaign for birth control. The movement is still in its infancy, but it is already apparent that the major obstacles derive from superstition, illiteracy and poverty. An enormous social effort will be needed if these are to be overcome in time to prevent a serious deterioration of conditions on the island; for the prevailing rate of increase means that the present population will have doubled well before the end of the century. Fortunately, the pressure of population is now to some extent alleviated by the fact that relatively large numbers of Barbadians are emigrating to Great Britain.

In Puerto Rico emigration on a scale almost sufficient to balance an annual net increase in population of over 2 per cent has also been a major factor in preventing the growth of population from nullifying the highly successful efforts made over the past 30 years to industrialize the country and raise its standard of living. This relatively enormous emigration has been possible only because Puerto Ricans enjoy United States citizenship and can move to the American mainland without any difficulty. Even so, the present rate of population growth remains a threat to prosperity, in spite of the fact the gross national product has almost doubled in the past 10 years and that the average net income has increased by 60 per cent.

The Government's attitude in this predominantly Roman Catholic country has been favourable to the spread of birth control clinics and to the dissemination through every possible medium, including the radio, of information about family limitation. As usual, opposition resulted in spreading far more widely a knowledge of the subject than would have been possible in ordinary circumstances. In spite, however, of the fact that birth control is a subject of ordinary conversation among Puerto Ricans, the available techniques by which it is practised are clearly inadequate to meet the need. The unfortunate consequence is that the method of fertility control which is most popular in

the island is the irrevocable step of surgical sterilization; women resort to it after they have had three or four children, and even the male population is now increasingly turning to it.

These are only a few examples of the widespread problem which faces the underdeveloped territories of the world in their efforts to control the fertility of their populations. The prospects are depressing. With populations increasing as fast as they are in India, China and the Caribbean Islands, it seems inevitable that the fruits of new economic development, instead of becoming available to raise the level of existence of those already living, will be swallowed up in the effort to cater for new additions. It is equally clear that illiteracy as well as the lack of adequate motivation make it extremely difficult for the people in the underdeveloped areas to employ Western methods for limiting the size of families.

THE OUTLOOK IN OVERPOPULATED AREAS

According to the classical picture, human population grows in a cycle. The first and primitive phase of this cycle is characterized by more or less stationary numbers due to very high mortality rates offsetting very high birth rates (fertility rates of well over 40 per 1,000 have been recorded in certain underdeveloped territories until quite recently). When living conditions, particularly the production and distribution of food, begin to improve, this static phase of sparse population gives way to a second phase, in which death rates begin to fall, while birth rates either remain constant or rise slightly as a result of the improved environmental conditions. The start of this second phase of the population cycle in England and Wales coincided with the start of the industrial revolution and is usually taken as 1750, the year in which the death rate began to decline, falling to a level of just above 20 per 1,000 in about 1820. The birth rate, however, continued to fluctuate about the level of 35 for some 130 years. As a result, the size of the population trebled over this period. On the other hand, in France, where death rates started to fall at about the same time as in England, birth rates also began to decline almost simultaneously, so that the natural rate of increase of France's population in the nineteenth century was very much less than that of England. This difference is usually attributed to the fact that industrialization was very slow to develop in France.

This middle and expanding phase of the population cycle comes to an end as soon as birth rates begin to fall. In England this demographic event was triggered by the Bradlaugh-Besant trial in 1877. Since then, the birth rate has fallen from a level of just over 35 per 1,000 to about 16 per 1,000.

The third and 'final' phase of the population cycle, according to the clas-

sical concept, is characterized by a stable birth rate which runs at a level slightly above that of the death rate. This result is what is to all intents and purposes a stable level of population.

According to this view of the way population grows, most of the underdeveloped territories of the world, and certainly the most heavily populated of them, are in the early stage of the expanding middle phase of the cycle. But there is a major difference between what is happening in countries like Ceylon, China and Trinidad today, and what happened in the Western world when it was in the corresponding phase of the population cycle. The difference is one of speed. Declines in mortality rates, which took decades to accomplish in Western Europe, have been brought about within the space of a few years in countries like Ceylon. The health measures which are now available to counter the spread of infectious disease, or to eliminate diseases like malaria, or to treat individual cases of sickness, are immeasurably superior to those which were available to the Western world in the latter part of the eighteenth and the first half of the nineteenth centuries.

The increases now taking place in the populations of many underdeveloped territories have no connexion whatsoever with an increased demand for labour. On the contrary, in practically every one of the countries concerned, there is increasing unemployment and under-employment—the by-products of the efforts that are now being made to improve social services and to foster industrialization. In fact, the threat to the development plans of all these countries is an increasing load of idle hands. If the part of the annual increase in the national product which goes to consumption is fairly distributed among the population, this situation need be no more than a very difficult phase in a process of economic and social development. But events in many countries do not encourage such a view. All that one can be sure of is that the problem would everywhere be simpler if the population were not multiplying as fast as it is. In that sense, the rapid growth of population in the underdeveloped territories of the world constitutes a real social problem which is in urgent need of solution.

But where is this solution to be found? No doubt, with the rise in the standards of living brought about by increasing industrialization in the underdeveloped countries, the rate of population growth will adjust itself to prevailing social opportunities—as it has usually done in the more developed parts of the world. On the other hand, raising the level of economic activity may at first have the effect of stimulating the birth rate. For example, the elimination of malaria may not only lower mortality rates, but, because of a general improvement in health, may even stimulate an increase in fertility. The elimination of venereal disease is also a normal consequence of the improvement of social conditions, and one which encourages a higher, not a lower birth rate. Similarly, a decrease in housing density could also result for a time in increased fertility.

In the short run, therefore, development programmes aimed at raising the level of economic activity are not enough by themselves; in addition, the people in the countries concerned should be made to realize the urgent need to limit the size of their families in order to improve their lot and to ensure that their children enjoy a greater expectation of life and better social opportunities. Women have to be persuaded that the larger their families, the greater the burden they have to bear, and the less the care they can give to each child. It is extremely difficult to spread views such as these in agricultural communities, where for hundreds of years children have been regarded as a source of labour, and therefore as a blessing and not a burden.

If a decline in fertility rate is in the interests of a community as a whole, it is clear that ways will have to be found to diminish individual opposition to measures of family limitation. Obviously, too, no widespread campaign for the control of fertility could hope to succeed unless it was associated with a campaign for the improvement of literacy and of social services such as schools and hospitals. Moreover, if a widespread national campaign for fertility control is to have any chance of succeeding, it would have to be supported by governmental funds, not only to pay the salaries of educationists, but also to cover the cost of such measures as they might be advocating.

All these things are either being planned or have already been started in countries such as India. Yet so far there is no sign that the national campaign for fertiliy control has made any impact on India's demographic problem. What has become clear in India, as in so many other areas, is not only that there is a direct relation between economic status and the recognition of the need to limit fertility, but also that action based upon a recognition of this need depends on the feasibility of the available techniques of birth control. As has already been said, those that are known today do not satisfy the need even in advanced countries. They are hardly likely to satisfy the far greater need which exists in impoverished, overpopulated and illiterate societies.

What everyone is hoping for, is some discovery which will allow people to control fertility simply, efficiently, harmlessly, reversibly and above all cheaply enough for the method to be within the reach of even the poorest countries. The image that has been conjured up is that of an 'anti-fertility pill' which can be taken by mouth as and when required. How near are we to discovering a substance which will temporarily and harmlessly inhibit the process of reproduction in the female or in the male? Before this question can be answered, it is necessary to refer to certain basic facts of reproductive physiology.

THE PROSPECTS FOR AN ANTI-FERTILITY 'PILL'

Spermatogenesis, the process by which the male germ cells are produced, goes on continuously from puberty into old age; but a woman enters upon her reproductive life with a finite number—of the order of half a million—of primordial egg cells, any one of which can develop into a ripe ovum, but the vast majority of which die without ever maturing. Both the elaboration of the male germ cell and the ripening of one or more of the egg cells with which the ovaries are furnished are dependent upon the proper functioning of the pituitary gland. If this gland, which lies at the base of the brain, is removed from the body by surgical operation, the testes and ovaries cease to function. The pituitary, and therefore reproductive function, can also be suppressed by pharmacological methods. Unfortunately, very few of the many laboratory techniques by which this can be achieved are applicable as practical methods of contraception. The basic principle behind all of them is that once the concentration of the sex hormones which the ovaries and testes themselves produce increases beyond a certain level in the blood stream, the pituitary becomes incapable of producing or releasing its own reproduction-stimulating hormones. Unfortunately, the concentration which the ovarian or testicular sex hormones have to reach for this to happen is generally associated with deleterious effects on other bodily functions.

The reproduction-stimulating principles of the pituitary can also be blocked by other substances, for example, the extracts of certain plants. This fact is equally the starting point of a search for a fertility-controlling pill. A third line which is being followed in the search for such a pill is the investigation of substances which interfere directly with the germ cell-producing tissues in the male, or with the stock of egg cells in the ovaries of the female. A fourth line of attack seeks ways of preventing, by means of drugs, either the process of fertilization, or that of implantation of the fertilized egg, or the development of the egg once it is implanted.

The greatest success so far claimed for the first line of attack relates to a hormone called progesterone, which is produced by the cells of the egg capsule in the ovary after the ovum has been discharged, and whose chemical nature is fully known. Progesterone has the specific property of transforming the lining of the uterus in such a way that it will allow the fertilized ovum to embed. Once an ovum that has already been liberated has begun to develop, progesterone also inhibits the ovary from discharging any more ova. It can even bring about the complete suppression of the functions of the ovary, so that ovulation does not occur at all.

Research on progesterone as an anti-fertility agent has had as its main object this last function; it is now clear that when given in large quantities by mouth it may inhibit ovulation in women as well as in laboratory animals, although part of its action as an anti-fertility agent may be due to the fact

that in large doses it induces an atypical development of the uterine lining. Further tests have now been made on a number of chemical substances related to progesterone, particularly on a substance called 19-nor-testosterone, to which a small amount of another related compound called oestrogen is added.

A group of 418 women belonging to the lowest economic and educational levels of the community co-operated in a large-scale trial which the Puerto Rico Family Planning Association carried out with this combination of drugs. All were under 40 years of age and had already borne two or more children. Half of them withdrew from the trial very soon; of the remainder, about seventy continued the treatment for more than a year. No pregnancy occurred in these seventy women during the period they took the 'pill' according to instructions, nor in a further 130 who persisted with the treatment for a shorter time than a year. Pregnancies were, however, reported as soon as the treatment was stopped. Unfortunately, a number of undesirable side-effects were also recorded, so that for the time being judgement must be reserved both on the report of the trial and on the value of this technique of fertility control.

Various plant extracts have also been tested to see whether they can suppress the function of the pituitary, or inhibit the sex-stimulating hormones of this gland once they have been released into the blood stream. These experiments were prompted by reports from many quarters about herbs capable of inducing either sterility or abortion. Scores of preparations have been tried, but the only two that are worth mentioning here are the weed *Lithospermum* and the pea *Pisum sativum*.

In trials of the first, it was immediately discovered that injections of extracts of all parts of the dried plant caused sterility in rats, and that this effect was due to the inactivation of the pituitary hormones responsible for stimulating the ovaries or testes. Efforts to isolate and purify the active principle of *Lithospermum* were unsuccessful, and research was further discouraged when it was found that *Lithospermum* might have some very undesirable side-effects, even if it were an anti-fertility agent. It was found, for example, that life expectancy is greatly reduced in test animals fed one variety of the weed; and that quite apart from suppressing the reproduction-stimulating principles of the pituitary gland, the extracts may also disturb certain pituitary functions which are vital to health.

Work with extracts of the pea *Pisum sativum* have been carried somewhat further, but in spite of considerable clinical trials in India, it is doubtful if the essential anti-fertility principle which the pea contains—2,6-dimethyl hydroquinone—is really as effective as it has been claimed to be. Even the Indian scientist who, in the absence of anything better, has done most to encourage the use of this substance as an oral contraceptive claims no more

for it than that it may produce a 'reasonable reduction' in pregnancy rates.[1] And since it is necessary to take it about the time ovulation is expected to occur in order to obtain even this limited effect, it is hardly a practical measure so far as the illiterate rural population of India is concerned. *Pisum sativum* has illumined a path, but has certainly not yet brought us to the goal.

Various efforts have also been made to find a substance, active by mouth, which will interfere directly with spermatogenesis in the male, or with the maturation of the already-formed oocytes in the female. One lead was provided by the observation that a class of chemicals called nitrofurans, as well as certain related compounds, can inhibit, in a reversible fashion, stages in the division of cells which lead to the formation of spermatozoa. The difficulty with these experiments is that the doses necessary to produce the desired effects on male reproductive capacity also produce highly undesirable disturbances in other bodily functions. Furthermore, the indications are that nitrofurans might take a considerable time to bring about the suppression of the testicular tubules in which the spermatozoa are formed, and that the time it would take to reverse the process might thus also be very prolonged.

Reports have now been published of another chemical substance, erucic acid, which may be decidedly more effective from this point of view.[2] This chemical, when fed to young male rats, leads to a reduction in spermatogenesis, and after about five months to complete sterility. During this period the animals grow normally and remain in excellent health. Adult male rats do not respond as readily as young ones, while adult females given erucic acid undergo normal sexual cycles. On the other hand, the young of these females usually die because of the defective development of their mother's mammary glands. While the nitrofurans exercise their action because they interfere with carbohydrate metabolism, erucic and other fatty acids do so because they disrupt the metabolism of the essential fatty acids. If further experiments confirm that this kind of metabolic disturbance is not undesirable in relation to other bodily functions, this new discovery will have opened up a far more promising path than that revealed by the nitrofurans.

As already observed, a woman enters on her reproductive life with a stock of egg-cells which gradually becomes depleted as she ages, and to which no new ones are added. It is also known that fertility is to some extent a function of the number of oocytes that exist in the ovaries, this fact being a partial explanation of the decline in fertility that occurs with age. Unfortunately, we know of no drug which, when taken by mouth, can reduce the number of oocytes. X-irradiation will bring about such a reduction, a given dose being associated with a predictable degree of loss in the size of the oocyte popu-

1. S. N. Sanyal, 'For an oral contraceptive', *J. Med. & Int. Med. Abstr.*, Vol. 21, No. 5, 1957.
2. K. K. Carroll & R. L. Noble, 'Influence of a dietary supplement of erucic acid and other fatty acids on fertility in the rat', *Can. J. Biochem. Physiol.*, Vol. 35, 1093, 1957.

lation. It is conceivable that this could be made the basis of a means of controlling fertility, but much remains to be done before this is proved.

Other lines which are being followed in the search for an anti-fertility pill are based upon the fact that it is possible to interfere either with the process of fertilization, or with the changes which occur in the lining of the uterus just before the fertilized egg is implanted, or with the metabolic processes which underlie the transformation of the fertilized egg into an embryo. Experimental work on animals with the class of drugs known as anti-histamines is yielding promising results so far as the second of these possibilities is concerned. Work with anti-metabolites, which inhibit embryonic development, has been taken even further but, unfortunately, has not yet reached a successful conclusion. For example, a chemical called aminopterin can bring about what is, in effect, the abortion of the embryo in its earliest stages. When, as sometimes happens, aminopterin does not produce its full effect, the embryo will continue to develop, and a malformed baby may be born. Much more experimental work therefore needs to be done with anti-metabolites before they are likely to be used on any wide scale in order to control fertility.

CONCLUSION

A dispassionate appraisal of all this current research inevitably leads to the conclusion that the hopes of finding a simple oral contraceptive that is sure in its action and has no undesirable side-effects are greater today than they were, say, two years ago. Even so, it would be foolhardy to take the view that the problem is likely to be solved in any specified period of time, if indeed ever.

Moreover, even if a 'pill' is discovered, it does not mean that it will be used on a wide scale in countries like India or the islands of the Caribbean, unless the people concerned, having been made to understand the reasons why they should limit their fertility, link this need directly in their minds with all the other measures aimed at improving their social status and their standards of living. It is a sobering thought that the Japanese national campaign to limit fertility has not yet managed to spread a knowledge of the subject sufficiently widely to prevent people from turning to abortion as the most usual and most certain method of fertility control. And yet Japan is flooded with literature on the subject; has numerous birth control clinics; and has gone to the length of training one instructor in the subject for every 3,000 of the population. Experience in the Caribbean equally emphasizes the enormous difficulties which have to be overcome before any 'pill' that may be discovered will break down the barriers of ignorance and apathy.

But the control of human fertility is not only a social and economic prob-

lem; it is also a human problem. Human misery is most intense where the national need for controlling fertility is greatest. Whatever the circumstances, repeated childbirths and a high rate of infantile mortality usually impose burdens on women which deny them any possibility of social advancement. Large families also mean less attention and care for each child. We need not doubt that reproductive rates will eventually fall as levels of economic activity rise. But the urgent question is how long this process in going to take. Mortality rates are declining more quickly than birth rates in all the underdeveloped and overpopulated territories of the world. An effective way of controlling fertility, were it available, would undoubtedly remove one of the main causes of the world's present load of social and political problems.

THE USE OF OCEANOGRAPHY

by

G. E. R. DEACON

Dr. Deacon, who is a Fellow of the Royal Society, is Director of the U.K. National Institute of Oceanography. He was Chairman of Unesco's International Advisory Committee on Marine Science in 1956-57, is Vice-Chairman of the Special Committee on Oceanic Research set up by the International Council of Scientific Unions, and a member of the Bureau of the International Union of Geodesy and Geophysics.

The Director of the world's largest marine laboratory recently gave a vivid picture of the disadvantages under which marine scientists have to work. First, he pointed out, there is the great disparity between the size of the area to be studied and the number of scientists actually engaged on the study. Although the ocean covers an area well over twice that covered by land surfaces, the number of oceanographers is infinitesimal in comparison with the number of scientists engaged in the study of the land.

Then there is the baffling opacity of the ocean which defies attempts to penetrate it except by such means as lowering measuring and sampling apparatus on long wires or by sending down into the depths of the ocean a few intrepid scientists in one of the only two safe bathyscaphes now in existence. But the performance of such measuring and sampling apparatus can only be assessed indirectly, and the observers in the bathyscaphe cannot see anything that is more than a few feet away. Acoustic methods, which send sound waves into the sea and seek to distinguish between different kinds of echoes, show increasing promise, but they are a poor substitute for our eyes, and for the telescopes and aerial photography which can be used on land.

Another limitation arises from the fact that waves, currents, water movements and sea conditions vary widely and as yet unpredictably with time and place, and that they can only be studied at the relatively few times and places accessible to research ships. Lastly, there is the disadvantage common to all large-scale problems in nature that little use can be made of controlled experiments—the forces involved are too large, and the time and space scales too great to be simulated in the laboratory. A well-known marine scientist has aptly summed up the position by asking how meteorologists would get on if they had to cover the whole of the northern hemisphere with half a dozen automobiles recording observations by flying kites on a moonless night.

However, it is not by enumerating the handicaps under which he has to work that the oceanographer can hope to rouse interest in, and win support for, marine science. Rather, he must point to the practical benefits that can be gained from the study of the ocean. He must show—if he can—that it will help us to get more food and raw materials from the sea—and that this can be done without prejudice to future supplies; that it will improve the use of the sea for navigation or for such purposes as the disposal of waste products; that defences against waves, storms, floods and the silting of harbours will become more effective as we learn more about the sea. In other words, he has to show in what ways oceanography can be of practical use.

FOOD FROM THE SEA

The ocean covers over 70 per cent of the earth's surface, and any part of it is, on an average, probably at least as fertile as an equivalent area of land. Naturally this fertility, and the same applies to the fertility of land surfaces, depends on a complex interaction of sunlight, nutrients and other environmental conditions which may vary considerably from one region to another.

To reap the harvest of the ocean is at least as difficult a task as that of reaping the harvest of the land. The bulk of marine life is in the form of microscopic plants and animals, usually known as plankton, which are neither easy to gather, nor agreeable to the human palate; we have therefore to rely almost entirely on their conversion into human food by fish and animals that have been nourished and fattened on them. In our ponds and streams we can practice some husbandry, but in the oceans we must still hunt for food and must face many of the problems that confront us on land. We are beginning to find that even in the most fertile areas stocks of profitable and edible fish are not inexhaustible, and that the profits of the chase depend on scientific knowledge, technical ingenuity and capital expenditure. The increase in the activity and efficiency of commercial trawling and the consequent impoverishment of favourite fiishing grounds have made it necessary to send ships farther afield and to intensify the drive for improved methods of detecting and catching fish. It is now possible for salmon to be taken in great numbers in the open ocean as well as in the rivers; tunny can be caught in mid-ocean areas far away from their traditionally known haunts; and whalers now have recourse to the modern methods of underwater detection and aerial observation. It is significant that the methods developed by whalers for operations in the most distant oceans of the world are now being applied to fisheries in the North Atlantic; factory ships and transports are tending more and more to take the place of shore bases.

The need to help fishermen to get a good and steady return for their work without impoverishing the fishing grounds themselves has done more than

anything to foster the study of the sea. This practical immediate aim has led to the specialization known as fisheries science; but it has also emphasized the need for precise study of all aspects of the ocean. This need has been greatest where there are large numbers of people who have long been dependent on food from the sea as well as from the land, and where long-established fisheries have become uneconomical, either through natural causes or as the result of intensive fishing. A paucity of fish unavoidably leads to friction, not only between fishermen but also between countries; and the best way of lessening such friction is to gain precise knowledge of the life histories, migrations and feeding habits of fish in relation to their environment. Given sufficient understanding of the changes in numbers and distribution, a realistic basis for satisfactory agreement can be established.

But the task of gaining such knowledge is a very difficult one, because fish populations are affected by different conditions during spawning, hatching, and larval and adult stages, and we know very little about which conditions are favourable and which are not. Bad weather, low temperatures and unfavourable currents may interfere with spawning and hatching; the success of the larval stages may depend on the presence of a particular current to take the larvae to favourable feeding grounds; and further development and growth of the adult may be determined by a whole range of physical and biological processes necessary to ensure favourable living conditions and adequate food supplies. The International Council for the Exploration of the Sea, formed 60 years ago by the countries of north-western Europe, has made good use of advances in knowledge and promoted many agreements on measures for regulating fisheries in the interests of all concerned. However, the number of disputes still occurring shows that much remains to be done in establishing facts and principles to prevent misinterpretations and misunderstandings.

A more pressing task, especially in countries with rapidly increasing populations, is the need to find and develop new fisheries. Sufficient light to cause photosynthesis is the first essential, but in temperate and lower latitudes, where there is plenty of sunshine, growth is often limited by shortage of nutrient salts, particularly phosphates and nitrates. Some guidance with respect to regions likely to be rich in nutrient salts can be gained by studying water movements. Warm surface water is generally separated from the colder deep water by a clearly defined transition layer in which the decrease in temperature causes sufficient increase in density to set up resistance to vertical mixing. There is thus a layer of relatively light water over one of greater density, and while the winter storms in cooler temperate latitudes are sufficient to mix them, in lower latitudes the boundary layer and resistance to vertical mixing persist all the year round. In these latitudes the continual plant growth in the surface layer uses up the nutrients or reduces them to very low concentration. The underlying deep water is rich in nutrients be-

cause of the decay of sinking organic matter and lack of light, but the amounts of these nutrients which find their way to the impoverished surface layer are small because of the absence of mixing between the cold and warm waters. Anything which tends to encourage upward movement of cold water and to increase mixing thus leads to richer growth at the surface, and the boundary of any current or the site of any sharp change in speed and direction of current is a likely place to look for the physical processes which lead to greater mixing. Any boundary in the ocean, especially if the land lies to the left of the direction of the current in the northern hemisphere or to the right in the southern hemisphere (because of the earth's rotation), is thus likely to be richer in food than off-shore water. But any change of depth, particularly at the edge of the continental shelf, may also cause upwelling; shoals and shallow waters around islands generally have a much richer flora and fauna than the deep water close at hand.

Far away from land, useful concentrations of fish have been found on boundaries of currents, such as that between the north equatorial current and the equatorial counter-current. New ocean surveys have been planned in the light of such knowledge, and an understanding of the dynamics of water movements can be as good a guide in extending salmon and tunny fisheries into the deep ocean as a knowledge of shoals and currents has been to shallow water fishing.

But while upwelling and mixing are overall guides to regions of high productivity, an understanding of the actual living and shoaling habits of fish also requires study. The areas richest in fish are not likely to be found where the water is coldest and contains most nutrients; it may be that water coming up from below has to remain some time at the surface before it can support a rich growth of plankton and fish. Most fish are thus generally found in the boundary regions between colder and warmer waters.

The distribution and shoaling habits of fish are also known to be affected by many other factors, such as winds, tides, currents, or perhaps an inlet of fresh water, and although there is often some local knowledge and experience available in this respect, there is too little systematized information on which further knowledge could be built. A better knowledge of water movements would also help to improve the operation of fishing gear and to develop new techniques, such as acoustic methods of finding, identifying and counting fish, whilst a better knowledge of local movements of fish (and prawns) would ensure a more regular supply, and thus a more economical operation of freezing and canning plants.

RAW MATERIALS FROM THE SEA

China still takes at least two million tons of common salt from the sea every year, and India extracts some one and a half million tons; the world total is about five million tons per year. This, of course, is an infinitesimal fraction of the total amount of salt in the ocean. The world production of magnesium from the sea probably amounts to about 300,000 tons per annum, and that of bromine to 100,000 tons. Many other chemical products are present in the sea, but they are so greatly diluted that no profitable methods for extracting them have yet been found. Potassium, for example, has been obtained from the ocean, but it is much more profitable to extract it from inland seas which are partly or completely dried up, such as the very saline Dead Sea or the marine deposits of Stassfurt (Germany), Alsace and New Mexico.

The Chilean nitrate deposits, not to be confused with those of guano, are also believed to be of marine origin. Some iodine is still produced from seaweed, but most of the world's supply comes from the Chilean nitrate beds and from concentrated natural brines. The ultimate origin of petroleum seems to be the decomposition of organic material at the bottom of former, very fertile, ocean basins; if this is true, the immensity of petroleum reserves gives some idea of the scale on which the ocean can produce organic material.

The present problems encountered in extracting chemicals from the sea are the problems of chemical engineering concerned with the handling and the concentrating of large volumes of water; but a better understanding of geochemical processes, particularly of sedimentation and of the conditions under which mineral oils were formed, is likely to be a useful guide to the finding of further deposits.

POWER FROM THE SEA

Schemes to obtain power from the sea encounter the same kind of difficulty as processes for extracting chemicals: tides, waves and currents contain large amounts of energy, but this energy is spread over such large areas or volumes of water that the installations needed to extract it would not be economical. Small tide-mills have operated since early times, but large-scale projects have come to nothing; the British scheme for the Severn barrage never materialized, and the Passamaquoddy scheme in the Bay of Fundy (Canada), started in 1935, was soon abandoned.

Technical developments in the design of turbines have opened up new possibilities, and a large project (360,000 kW) intended to produce 800 million kWh per annum has been started in France in the Rance estuary. This project is due to be completed in 1960 and, if successful, may lead to a much

larger scheme embracing the Mont-Saint-Michel Bay and producing the equivalent of about half the electricity now consumed in France. Plans are also being discussed for another attempt in the Bay of Fundy. Such projects demand not only specialist knowledge of the tides and currents, but also a careful assessment of their effects on navigation, fisheries, and the configuration of coasts and beaches in the neighbourhood.

The power of waves is obvious to anyone who has seen the damage they can inflict; many a storm hits the coast with a force of a million horse-power per mile of coastline. But it would require an enormous engine to tap this force, and the operation would be more difficult than using the energy of tides. Small installations have been tried; a wave-pump with an output of about one-half horse-power under favourable conditions worked for 10 years at Monaco; an installation in Newfoundland produced enough electricity to light a small house. These and similar schemes combined with the use of new techniques and materials seem reasonable enough to warrant a more thorough study of wave conditions.

Utilization of the relatively large and steady differences of temperature between surface and deep water in the tropical seas has engaged the attention of French engineers for many years, and an experimental plant at Abidjan, on the Ivory Coast, will soon be completed. This plant will produce large quantities of salt and fresh water as well as electricity.

NAVIGATION

Our greatest use of the sea is as a cheap highway for commerce; and although the ships of today are well able to face winds, waves and currents, there is little doubt that time could be saved, and loss and damage avoided, if wave conditions and day-to-day changes in currents could be predicted reliably from weather charts and forecasts. The rewards will not be as spectacular as they were a hundred years ago when, by paying due attention to the new charts of prevailing winds and currents, a passage might be shortened by several weeks; but they will still be substantial. Ships' captains may not take kindly to following changing sailing directions from the shore; but the practice has been tried in a small way and has shown that ships can avoid storms and save time with less risk of damage.

The study of ship movements in relation to waves has recently progressed to the stage where direct use can be made of reliable wave predictions. Much useful work has been done in this direction, and a number of authors have independently proposed formulae by which the main features of the wave pattern can be predicted from the speed, direction and duration of the wind in the locality and in the adjoining ocean areas which contribute swell. These predictions are, however, of an empirical nature and have mainly local

validity; much more work must be done before they can be of general validity and universal application. Such work would undoubtedly prove useful in the design of ships' hulls and in laying down operating speeds to suit different wave conditions, as well as in providing essential data for harbour design, coastal engineering, loading and unloading in exposed anchorages, passage over harbour bars, salvage operations and oil drilling.

We already have excellent charts of the prevailing ocean currents, but these charts are careful to point out that day-to-day speeds and directions are variable, even in regions of strong current. The first observations in the Gulf Stream, made more than a hundred years ago, showed that the current was unsteady, and that it shifted its position so that the set varied in strength and direction, especially at the edges of the current. Since then, the averaging of many thousands of observations has tended to encourage geographers to represent the stream as broader and weaker than it really is. New observations between Cape Hatteras and Cape Cod, made with the help of modern radio-navigational aids, show that the set in the fastest part of the current is often greater than is usually supposed; it reaches as much as 4 to 5 knots in a narrow region 10 to 15 miles wide near the landward side of the current. The observations show eddies varying from a few miles across to several hundred miles, and they also show that on occasion there can be strong counter-currents even near the usual axis of the current. Experiments by tanker companies operating along the U.S. Atlantic seaboard have shown that seeking out the strongest part of the current can save time. In regions of variable current a better understanding of the physical processes involved might improve safety measures.

Although the techniques of recording, analysing and predicting tides and tidal streams are already very effective, long series of observations cannot be made at every place for which predictions are required. To make the best use of a short or remote series of observations calls for a clear understanding of the effect of the tide-raising forces on seas of different size and shape, and of the factors which modify a tidal wave entering shallow water.

COASTAL AND HARBOUR ENGINEERING

There are many potentially useful applications of tidal studies in connexion with the changes in estuaries and channels brought about by silting and erosion. In fact, the interests of hydraulic engineers and marine scientists are closely linked and it has been said that the domain of hydraulics extends seaward as far as low-water mark, whereas that of oceanography extends landward as far as high-water mark. The bottom current is often different from that at the surface, so that silt and salt creep up the river estuary in

spite of the greater outward flow of water at the surface. Better understanding of the mechanism by which both currents change speed and direction might well save some of the large sums spent on dredging.

Experience and sound engineering are essential to the design of coastal defences, but they will not be able to be used to the best advantage until our basic knowledge of tides, waves and beach currents reaches a more advanced stage. This lack of knowledge is usually offset by allowing a large margin of safety in engineering construction; but this often puts up costs so high as to make them prohibitive. Wave recorders, which allow us to gain a better understanding of various types of beach movement, are now available and are being installed in many places where constructional work is planned. It has been found that short steep waves are most effective in eroding beaches and depositing the eroded material at greater depths to seaward of the beach; low long swell returns the material to the beach, but if it comes at an angle to the beach it is very effective in moving material along the coast. Similar factors influence the growth and movements of bars, which can be a nuisance in the approaches to a harbour.

It is not likely that a simple and elegant solution can be found to all these problems. But most of the effort in coastal engineering aims at preventing beach material from being moved from some parts of the coast where it is needed to protect the land, to other parts where it is a hindrance to navigation; and it is only reasonable to assume that this work may be done with greater efficiency and economy when we have gained a better understanding of the physical processes involved. It may be added that a better knowledge of beach currents, especially the dangerous 'rip currents', would reduce the number of deaths from drowning.

Coasts and harbours are affected by surges and long waves which are of a type intermediate between ordinary waves and tides. One of the most common types is the surf beat—an oscillation associated with the more or less regular occurrence of groups of high and low swell approaching an ocean coast. The water level rises and falls several inches—and in exceptional conditions nearly a foot—over a period of two to three minutes. Many harbours have this surf beat, and the backward and forward oscillations can be sufficient to damage ships moored to a quay and to snap the mooring ropes if these are not kept continuously tight. The surf can also set up unpredictable movements near harbour mouths and pier heads, which may add considerably to the difficulty of handling ships entering or leaving a harbour. Although the number of major ports seriously affected by this range action, as it is called, is small, there are some ports, such as Cape Town and Madras, where it is a serious problem. The recent International Navigational Congress (1957) urged that research be undertaken in order to establish the causes of the phenomenon, to predict disturbances likely to cause danger to shipping, to study the results of long-period waves, and to devise alleviating and remedial

measures. Some evidence of increased silting due to this kind of oscillation was put forward at the congress.

There are other kinds of oscillation which may contribute to the range action; long-wave energy may be transmitted from distant storms, and natural oscillations are also present in gulfs, bays, channels and larger areas of water such as the continental shelves. In small bodies of water shut off from the large oceans these oscillations are often more prominent than the tides; round the ocean coasts themselves their effect can be seen on tide-gauge records, which every now and then take on a saw-tooth appearance as the regular rise and fall of the tide is disturbed by the local oscillations. We know very little about the causes of these oscillations, but it is presumed that local meteorological conditions have much to do with them. Experience shows that, in the case of long waves started by submarine earthquakes, the energy contained in a short burst of long waves coming from the deep ocean can be trapped in slower waves running along a continental margin, so that oscillations in a coastal region may persist for several days. There is also a possibility that disturbances may be prolonged by multiple reflections and refractions at the ocean boundaries, islands and shoals.

It is not known whether long waves can be generated in deep water, but in shallow water (50 fathoms) it is not unusual for a long wave to travel at the same speed as a meteorological disturbance (60 knots), and in such conditions the wave, once started, is continually energized. This happens every now and then in the English Channel; a small change in wind or atmospheric pressure travelling at just the right speed causes a long wave, and an observer on the beach can see the water ebb and flow several feet in as many minutes. Coming quite unexpectedly, it can cause considerable confusion among small craft near the beach and some trouble to people on the beach.

The giant surges in the path of a hurricane, and when water is piled against a coast by a strong wind, are of much longer duration; they no longer appear as irregularities on a tide curve, but are as large as the tides themselves. Coasts near the path of typhoons and hurricanes and those with a wide shallow shelf extending towards oncoming storms are the most vulnerable to flooding. They are the subject of intensive study in many countries with a view to predicting their occurrence in time for all possible precautions to be taken, and to estimating the maximum height likely to be reached by the tidal waves so that appropriate defences can be planned.

The study of all the effects meteorological conditions may have on water level is likely to be of considerable importance to navigation as well as to coastal engineering, because winds and variations in atmospheric pressure often significantly change the actual depth of water in a channel or over a bar. Even now it would pay most large harbour authorities to set up a small team to predict these meteorological disturbances of the tides.

MEAN SEA LEVEL

Industrial development of land near sea level—some of it reclaimed land—is now so great that changes in mean sea level, which may be quite significant over a period of 20 years or so, could have serious implications. The question is also important in geodetic levelling, where the results depend on information about changes in the volume of water in the oceans and about movements of water from one region to another, as well as on information about changes in the shape of the earth's crust. Mean sea level is obtained by reading the water level every hour from a tide-gauge record and averaging the readings over a month or a year, with some allowance at the beginning and end of the readings to avoid falsifying the average by including part of an uncompleted cycle of the main semi-diurnal or diurnal tide.

It has long been known that there are appreciable changes in mean sea level from month to month and from year to year, and that these changes are not merely local, but extend to separate and distant places. In most regions the monthly averages show an annual cycle, with the lowest mean level in spring and the highest in autumn. This is roughly what might be expected from seasonal changes in the density of the water and in the balance between precipitation and evaporation. The annual range of monthly mean level varies from a few centimetres at oceanic islands in the tropics to as much as 165 cm. in the Bay of Bengal. More complete knowledge of these variations will help scientists to study changes of climate, exchanges of water between sea, air and land, and the world-wide circulation of water. It also has some bearing on the problems of coastal engineering and geodetic levelling.

Study of the yearly averages shows that there are fluctuations from year to year as well as from season to season. On the Atlantic coast of the U.S.A., these fluctuations are generally less than 2 cm., but occasionally they may be as much as 5 cm. Between 1930 and 1949 there was an overall rise of 10 cm. of the water level in relation to the land. At Newlyn, near the south-west extremity of England, the changes from year to year can be as much as 7.5 cm., and there has been an overall rise in level of 6 cm. over the past 40 years. These fluctuations, like the seasonal changes, probably depend on varying climatic conditions. The long-term rise is generally attributed to the melting of glaciers and polar icecaps, but in some regions subsidence or elevation of the land due to modifications in the earth's crust may be as important as changes in the level of the ocean. Although the southern part of England seems to be sinking in relation to the sea level, there is no change on the east coast of Scotland. Much has been written on the subject in the light of historical, archaeological and geographical evidence and of tide records, but quantitative study is difficult without larger and more detailed measurements of both land and sea levels and without more knowledge of

modifications in ice cover. Some of the changes—reaching as much as 15 cm. in 100 years in certain cases—are sufficiently large to warrant serious consideration in the planning and cost of sea walls.

EFFECT OF OCEANS ON CLIMATE

The atmosphere is very transparent to the sun's short-wave radiation, little of which is absorbed and that mainly by the water vapour and carbon dioxide in the air. Nearly half of the incoming radiation is reflected by the clouds and the surface of the sea and land; the rest is absorbed by the water and land surfaces. Storage by water is more efficient, first because water needs five times as much heat as does rock to raise its temperature by the same amount, and then because the overturning and mixing of water makes it store its heat deep down as well as at the surface. In the temperate regions, the effect of summer heating can often be detected down to 100 m. by the end of the season. Because of the greater specific heat of water and because of mixing, the day temperature rises less, and the night temperature falls less, at sea than on land. In the Sahara the night temperature can be 30°C. less than the day temperature, but in the same latitude over the ocean the difference is likely to be less than 2°C. Whence the contrast between maritime climate and continental climate.

Winds and currents play a large part in controlling climate. As far as we know, there is a rough balance of incoming and outgoing radiation over the world as a whole, but there are significant differences between one region and another. Winds and currents prevent the hot climates from getting hotter and the cold from getting colder by transporting large amounts of heat, mainly from lower to higher latitudes. The atmosphere has an active circulation, probably because it receives heat at the bottom from the land and sea, mainly by conduction and from water vapour, and is cooled at the top by radiation to space. But the oceans are heated and cooled at the same level, since the inward and outward radiation and the transfer of heat to the atmosphere have their main effect at the surface, and this cannot produce very active convection. It has been estimated that the kinetic energy in the oceans is only about 2 per cent of what it is in the atmosphere, and that most of this small fraction is derived from the atmosphere through the drag of the wind. But although the water movements are slow, they carry large amounts of heat and do much to determine the place at which most heat is fed to the atmosphere. In this way they influence cloudiness, the radiation balance and winds. Winds and currents also influence the density layering in the ocean, and this in turn affects the response of the water to the wind and to differences of climate.

The interrelation of all these factors is too complex to be easily under-

stood, but more and more emphasis is being placed on the need for comprehensive study. The lower atmosphere gets most of its heat from the sea, and a fuller understanding of the processes involved is needed to improve methods of forecasting warm, cold, wet and dry periods for the benefit of food growers. Such knowledge may be useful in studies of weather as well as of climate, particularly in predicting hurricanes and typhoons, which all start over the ocean. It is also needed with respect to the oceans themselves—to enable fisheries scientists to predict how changes in wind and climate are likely to affect the water conditions in a fishing ground; and in the shorter run, to enable navigators to judge how particular wind conditions will affect a current.

The study of long-term trends in climate based on biological, geological and archaeological evidence is of interest to many branches of science—and has also some more immediate practical importance. The question of sea level is one example, since it is important to know whether the present rising trend is likely to continue. Another interesting example is the question of the average carbon dioxide content of the atmosphere; there is a possibility that this content is being increased by the growing expansion of industrial processes. The idea was previously dismissed on the grounds that the part played by carbon dioxide in absorbing the long-wave radiation sent out by the earth was small compared with that of water vapour, and that in any case the carbon dioxide content of the atmosphere was controlled by the oceans, which have an almost infinite capacity for taking it into chemical combination as well as into solution. New estimates have revived the discussion, the idea being that by our present enormous consumption of coal and oil we are building a more effective greenhouse roof over our heads. This and other theories have been put forward to account for historical climatic changes. The idea must be given careful consideration, since a significant rise in the mean temperature would mean a reduction in ice cover of the arctic and antarctic seas and lands which, in turn, would accelerate the rise of temperature by reducing the reflection of the sun's radiation and increasing the absorption. Such a train of events might provoke quite important changes in climate and sea level.

WASTE DISPOSAL

One of the greatest uses of the sea is as a receptacle for the disposal of waste. The opportunity thus offered has been so much abused near large towns or industrial centres that bathing has to be prohibited, and there is even some risk of disease. A satisfactory answer to the problem calls for a clearer understanding of the processes of diffusion and mixing, and of the manner in which they depend on waves, tides and currents. The disposal of atomic

waste has not so far been a difficult problem, since the amounts are small and are likely to decrease further as new uses are found for radio-active waste. But we should keep in mind the object lesson provided by previous experience in air and water pollution—where the threat has so long been ignored that it has now become a formidable menace. Short-term measures based on inadequate knowledge and taken under pressure from interested parties have not usually been satisfactory.

Although the spread of water from the River Thames across the North Sea seems to have a good rather than bad effect on fish populations, the general impression everywhere is that fisheries and weed beds are declining; and we are not certain that we are not gradually poisoning the oceans. More research will at least give a clearer picture of local problems and provide a foundation for a campaign to keep the sea clean similar to that launched against indiscriminate oil fuel disposal.

RESEARCH IN MARINE SCIENCE

The part which the sea has played in the cultural, economic and political history of mankind has always been a great stimulus to the study of the oceans. But in contrast with the wealth of literature on the achievements of the early explorers and geographers, there is no well-balanced account of scientific investigations of the ocean; Krummel's *Handbuch der Ozeanographie*[1] is perhaps the best guide. Early scientists like Boyle and Newton took a great interest in the problems of the sea, as did later Lavoisier, Bernouilli, Laplace, Young and others. Since the rapid growth of natural history in the nineteenth century, the main interest in the study of the ocean has centred on biological aspects, and today this interest is heightened by the fact that some of the fundamental problems in zoology can best be studied by using the simplest forms of life—which occur in the sea—and also that the results of such study are of practical importance to fisheries. But biologists themselves have always stressed the importance of studying the physical aspects of the ocean, i.e. water movements, since these must exert a great influence on the growth and distribution of the fauna.

Since oceanography clearly has a bearing on sea warfare and defence, it is not surprising that the two world wars should have greatly stimulated the study of the physical aspects of marine science. The claims of defence, navigation, coastal protection and harbour engineering, together with the realization that the latest research techniques can give valuable results when applied to the study of the ocean, have greatly contributed to the development of these aspects of marine science. The new physical studies are adding to the interest

1. The first volume published in 1907, the second in 1911.

of biological studies, but they require rather expensive facilities. Most of the work is being done or fostered by government-sponsored organizations which often co-operate when their interests coincide.

Useful work in the study of marine problems relating to fisheries has been done by the International Council for the Exploration of the Sea mentioned earlier. Since its inception 60 years ago, other regional groups have been formed. There is also the work of the international scientific unions, and the International Union of Geodesy and Geophysics has an International Association of Physical Oceanography, which used to cover most aspects of marine research, but which now confines itself to the physical, chemical and geological aspects only. The International Union of Biological Sciences, although it deals with marine studies, has no separate association for them.

Recently Unesco initiated a marine science programme. Its main object is to cultivate interest in oceanography, particularly in countries where it has not received sufficient attention. Pending the gradual development of a full-scale programme, international and regional co-operation is being stimulated by means of symposia on regional problems, fellowships, visiting lectureships and training courses. Unesco is also endeavouring to get interested countries to build and operate a research ship, and is bringing together scientists to lay the foundations of regional co-operation in survey and research. Another task assumed by Unesco has been that of acting as agent for the United Nations Organization in assembling information relating to problems common to many countries, such as the disposal of atomic waste and the regulation of the scientific investigation and exploitation of the continental shelves. The main task of cultivating interest in the subject and of promoting co-operation and a free exchange of ideas is one which Unesco with its area offices is well equipped to do.

The International Council of Scientific Unions (ICSU), to which Unesco makes a large annual grant, is promoting research at higher levels. It encourages and co-ordinates the activities of the scientific unions and furthers their mutual efforts in connexion with subjects not adequately covered by existing arrangements. It has responded to the needs of marine science by setting up a Special Committee on Oceanic Research, which has put forward a well-considered plan for collaboration in studying the deep oceans. A start is likely to be made in the Indian Ocean, and a number of working groups representing all aspects of the subject are now being formed.

As can be seen from this short account, various interests of importance to many nations are involved in the study of the ocean. There must therefore be a good deal of international co-operation both in conducting oceanographic studies and in disseminating their results. It is only thus that we can reach that fuller understanding of the ocean which will help mankind to derive greater enjoyment from the blessings of the land.

TECHNOLOGY AND PRODUCT DESIGN

by

JOHN GRAY

The author was on the information staff of the Council of Industrial Design in London from 1950 to 1953, and since then has been a regular contributor to its magazine Design. *He made a short study on the economic and managerial aspects of design at the research institute Political and Economic Planning (PEP) in London in 1955.*

THE EVOLUTION OF DESIGNING

Before the Industrial Revolution all designers were craftsmen, and most craftsmen were designers. Once they had learnt all about their materials and had by trial and error evolved their simple methods, they were free to create at will, using the simplest of machinery or no machinery at all. The industrial artist resembled the painter or the sculptor in that he conceived a basic design, worked it out in terms of the chosen materials, and then brought it to life by slow and patient craftsmanship. True, he differed from the pure artist in that, once famous, he could delegate the actual construction to skilled staff working under supervision, or even to separate firms operating under licence—as Chippendale did. But he could never do so until he had perfected the design in his own workshops.

In the machine age the character of designing has changed almost beyond recognition. Here and there in industrialized countries the crafts still survive, notably hand pottery, glass and metal ware, wood carving and marquetry. Only occasionally have craftsmen been required to learn a new technique—for instance, the potter has had to learn to operate the electric kiln and the inlay woodworker to learn new methods of bonding. But nowadays craftsmen ply a luxury trade; the bread-and-butter in their industries is earned by mass producers using modern machinery and methods, while the craftsmen are confined to specialized work, such as the painting of pottery or the acid-etching of glass. In modern factories, especially in the science-based industries, they have to be identified by the name of 'hand-craftsmen', the title 'craftsmen' being reserved for skilled tool-makers and jobbing and maintenance men in order to distinguish them from operatives and labourers.

From the very start the machine age bred two new types—the design engineer and the industrial designer or, as he is sometimes called, the stylist. The design engineer was essentially a technical man, a Stephenson or a Brunel. His job was to make a rigid structure or a mechanical assembly

which would give satisfactory service over a long period. The first of these great constructional and mechanical engineers often proved to be exceptionally good stylists because, pioneering new fields, they made a severe and simple approach to problems of designing. While inheriting the technical background of craftsmen, they had very little craft tradition; they did not claim to be artists, and if their work achieved beauty and grandeur, as in the early bridges, locomotives and steamships, that was a mere by-product of their engineering achievement. Their approach to design was what we now call 'functional'; it rested on the legacy of the stonemason, the boat-builder and the wheelwright.

The industrial designer, on the other hand, was essentially the offshoot of the artist-craftsman, not a technical man in the engineer's use of the term, but one interested in coaxing from the machine something as beautiful as craft work. He confined himself to work that machinery was taking over from the craftsmen; coach-building for the railways was a good early example. Since the process of mechanization was gradual, the designer remained essentially a craftsman throughout the nineteenth century; but as time went on, he became concerned less with day-to-day manufacture and more with the production-engineering aspects of design.

The Evolution of the Design Engineer

As modern technology advanced and industrial processes became more and more specialized, the design engineer underwent further transformation. Design problems became very complex, and in many engineering factories design teams emerged, one member of the team being mainly concerned with the appearance of finished goods.

During the same period research and development took root in industry, and design staff had to learn to co-operate with research workers, especially at the pilot-plant stage, so as to make quick and effective use of new materials and techniques.

Finally, the spread of mass-consumption completely altered the market for industrially designed goods. Working-class families, which formerly subsisted in bare houses on the mere necessities of life, found themselves able to afford suites of furniture, sets of kitchen utensils, textiles for furnishing, and a host of cheap luxuries. This was a new market with no design tradition and no developed taste. About the same time the middle classes grew considerably in numbers and influence; they were equally lacking in tradition and taste, but were pretentious and eager to ape (and perhaps to bowdlerize) the tradition and taste of their earlier counterparts. This trend emerged in an age when the cycle of fashion was already leading craftsmen away from the elegant simplicity of neoclassical design to increasing and sometimes excessive ornament—following the pattern of Louis XV France and Regency

Britain. It proved easy for the *nouveau riche* to carry ornament to absurd lengths.

While these changes were taking place, design engineers, becoming ever more specialized and research-minded, tended to lose their touch with the new market. But they soon found that their employers were only too anxious to meet this new demand. They then had to graft the *clichés* of current taste on to objects of engineering origin—to put curlicues on sewing machines and cabriole legs on refrigerators. Purely utilitarian mechanisms, such as machines and machine tools, retained the rugged and honest simplicity of early days—though they lacked finish by modern standards, because they underwent no conscious styling. But mass-produced consumer goods seemed increasingly to be meeting, rather than leading or reforming, the debased popular standards of the day. As a group, the engineers never absorbed the craft tradition; and as their products drove craft work off the market, the general level of design fell considerably.

The Evolution of the Industrial Designer

The first reaction to this trend came from craftsmen. These men were as little at home with machines as engineers were with the crafts, and at first they blamed the decline in taste and quality on the mere presence of machines. believing that they could somehow put back the clock. But though their iconoclasm had little effect, their creative work exercised a marked influence on thinking people, mainly because it abandoned the excessive ornament of the late nineteenth century, refused to copy ancient and exotic styles for modern purposes, spurned the vulgar and the specious, and reinstated the basic principles of design.

The early workshops of the modern movement were entirely craft-based. But it was not long before machinery crept in. Thus, the principles formulated by the rebel craftsmen were put to practical use, but their odd, unrealistic views about factory production were quietly forgotten. The modern artist-craftsman thought out his designs in terms of machine production—though on a small scale—and not in terms of handicraft. He soon found that, once he had accepted the conventions of machines, they could help him to create works at least as distinguished in appearance as those his forebears had made by hand.

By the early years of this century it was by no means uncommon for craftsmen to form their own companies with the backing of their own families or of well-wishers, and to sell very good designs which went against the current trend of popular taste. One thinks of the furniture designers Heal and Russell in Britain, of the glassworks of Hald and the furniture firm of Hansen in Scandinavia, the unique Bauhaus school of design and architecture in Germany and of the many disciples of the American architect Frank

Lloyd Wright. Other craftsmen were employed by progressive firms interested in improving the level of design. This movement gave a welcome impetus to industrial designers; instead of confining themselves to jobs which the design engineer could not tackle, such as coach-building, they began to permeate the whole field of mass-production, bringing back the honest approach to design that had been lost in the general debasement of taste.

Like the early engineer the modern designer put supreme emphasis on functional efficiency. His slogan 'fitness for purpose' became a catchword, implying that if a product is fit for its purpose it is therefore well designed. If enough attention is given to the basic shape of an article, that alone can make it a thing of beauty. Indeed a basic design may have decorative qualities—for example, in the grain of the wood or in the lattice work of the structure. Additional decoration is superfluous, and in extreme cases can even be a nuisance.

It is no wonder that men and women of this persuasion produced so many plain and arid designs between the wars. Yet by reverting to the basic principles governing shape and texture, they laid a foundation on which a new movement could grow. Today the movement is much more mature, versatile and less self-conscious. The approach to decoration, though still hesitant, is much less hidebound. There is a marked readiness to admit that certain consumer goods must contain an element of the designer's personal taste, whereas others, especially articles for the kitchen and toolshed, need only show lip-service to the principles of design.

Thus, during the growth of mass production the industrial designer has been weaned from the crafts, and led through a period of stark simplicity to a more gentle, though still maturing, approach to machine design. The design engineer, on the other hand, has lost the initiative in 'appearance' design because he has had no artistic tradition with which to combat the debasing influence of mass production. His main concern is that mechanisms should be technically sound; he may have to concern himself with matters like ease of operation and maintenance, durability, and consistency of performance; but he is not often able to style a consumer product effectively unless he collaborates with an industrial designer.

A Problem of Integration

So far as industrial design is concerned, modern industry can be divided into three broad groups. First, craft-based trades in which a staff or consultant designer works closely with the works manager and follows each design carefully through all stages. Second, capital-goods industries making equipment in which appearance design is a matter of encasing mechanisms made of simply shaped and compactly arranged parts—a task which can often be entrusted to design engineers who show special aptitude for it. Third, the

bulk of mass-production engineering where the stylist is only one member —though a very important one—of a design team which is mainly concerned with technical matters.

In all three groups the same problem has long been apparent: where does the industrial designer come in—at what stage should he be brought in, how much authority should he be given, and where should the balance be struck between his ideas and those of other members of the team? But the nature of this problem varies from one group to another. In the first group, and to some extent in the third, the industrial designer must have more scope than in the second, for he is expected to express his personality with a given material and by various techniques. At the other extreme, the designer of a machine tool or an instrument is clearly limited by the intricacy of the mechanism and by the comparative unimportance of styling in equipment made to a very close specification. Firms all over the world are still groping with this problem, trying to see how and at what point the two types produced by the industrial revolution—the design engineer and the industrial engineer—should be brought together on the job.

There is much evidence to show that with every technical advance the problem of designing becomes more complex, and the practical demands on both design engineer and industrial designer increase. Automation is a case in point. It stimulates the invention of new manufacturing methods (such as printed radio circuits) to replace those not yet capable of becoming automatic; but this sometimes necessitates radical changes in the design of the final product.

The specific problems that changes in technology have imposed on design today are four in number: problems of designing in new materials; problems of designing for production by new techniques; problems of function in condition of mass production; and problems of organization.

DESIGNING FOR NEW MATERIALS

There are two ways of designing for new materials. One is to keep within the limits of their proved ability. The other is to experiment beyond these limits on a small commercial scale. By and large, the designer with a sound engineering background is inclined to be cautious, while the appearance designer is more ready to take a chance. Resin-bonded glass fibre, for example, is finding a host of new uses every year, and many observers predict a big future for it in such things as car bodies. The material appeals to the appearance designer because it is very pliable before setting, and can be moulded inexpensively into novel and interesting shapes which would be too expensive to manufacture in steel sheet. As a result, a number of small firms have employed designers to style bodies in this material for the luxury market. The approach of the mass producers, however, is much more ten-

tative. They see obvious advantages in the material (no rusting, for example) but they look for certain improvements, notably in resistance to impact, before committing themselves to a major change-over. Moreover, they must keep an eye on potentially competing materials, such as plastic-bonded steel sheet.

Plastics

The plastics industry as a whole exemplifies the problems created by new materials. Almost every designer and manufacturer has at some time or other used plastics materials for purposes to which they are not suited. It could hardly be otherwise in such a fast-growing industry of such wide scope. But fewer mistakes occur today than ten or twenty years ago. As the industry has grown, it has produced a much wider range of materials, including a much more varied combination of properties; it is now possible to choose from several likely materials the one best fitted technically for each job, or even to modify a material in order to make it more suitable for a given purpose. For example, when designing a plastics casing for a telephone, one may choose a thermo-setting material, which resists scratches and grease, but easily breaks; or a thermoplastics material, which can be thrown across a room with impunity, but is easily scratched and marked by greasy fingers; or a modification which gives something, if not the best, of both worlds. We are rapidly approaching the stage when the right—or very nearly right—material can be found for almost every combination of conditions in which plastics cases are used.

Some plastics have established clear superiority over others in certain fields. Designers naturally choose polyethylene for aerosol bottles, for children's cups and beakers, for kitchen-sink furniture and for any other use in which its peculiar combination of pliability, softness and unbreakability makes it specially suitable. Melamine, though more expensive than many other plastics, is quickly establishing itself as a serious competitor to pottery in tableware; it feels like pottery, leaving no taste, and in addition does not easily chip, crack or break. Nylon, because of its strength, can be used in a much finer thread than other synthetic fibres. Similarly, no plastics can rival it for such uses as cogwheels (e.g., for food mixers), where it is both silent and hard wearing. Again, laminated polyvinylchloride sheets give the best combination of efficiency and economy.

But there is still a large range of goods for which the order of merit of various plastics has not been finally decided on technical grounds, even though all these plastics may have been commercially available for ten years or more. This is so because materials are being continually improved and their potential uses extended, so that the advantages that one holds over another may be short-lived. It is therefore important for designers to keep in

close touch with plastics manufacturers. The current trend is for plastics manufacturers to produce materials and components as well as finished goods; thus their staff designers are enabled to learn the potentialities of each material. The manufacturers also volunteer practical advice to architects and designers in the use of plastics in combination with other materials for furniture, fittings, electrical installations, instruments, etc. Plastics goods have consequently lost their old reputation of being cheap-looking and trashy, and have become more elegant and more practical.

Stainless Steel

Stainless steel is a tough, attractive and almost rustless material, but it is very expensive and difficult to work. These two drawbacks have until now limited its use much more severely than many experts thought likely thirty years ago. It finds most of its important outlets in products that have no strong design content.

In several countries manufacturers of stainless steel have sought to interest designers in this material. But it has proved difficult to turn the designs into a commercial success, though Sweden and Germany have in recent years produced interesting cutlery sets and table ware, and other countries are beginning to follow suit. The difficulty is that decorative metalware for the home is mostly electro-plated alloy and is made in factories that stem from the traditional silversmiths. But producing articles of stainless steel is essentially an engineering process; inded the very hardness of the material gives little scope for the craft of the silversmith, and the designer has to rely for both shape and decorative effect on the power of the press and the skill of the spinning lathe. Thus, to fashion objects in stainless steel, either a metalware firm must jettison its traditional methods in one sweep, or an engineering firm must make its entry into a new line of business against well established competition. Whichever happens, the new material starts with a big disadvantage—high initial cost. If manufacturers copy the traditional styles which are still profitable to the electro-plate specialists, they find it almost impossible to keep their prices competitive, except in the luxury market.

Paradoxically enough, it is the industrial designer, with his predilection for a simple use of material, who has shown the way to treat a metal difficult to work. By designing so as to reduce processing costs to a minimum, he has enabled pots, bowls, dishes and cutlery, all relying for their respective effect on bare outlines with matt finishes, to sell competitively with more ornamental plated ware. One story illustrates this point well. An English designer, under contract to a manufacturer of domestic goods in stainless steel, was asked to design a simple salt cellar and pepper pot. With little factory experience, he one day saw in the works a consignment of steel tubes

being cut diagonally, each tube providing the outline of two spouts for teapots. He collected a pair, had the insides of the square ends rifled to hold a screw-on plastics base, and asked for oval plates to be welded on to the oblique ends, one with holes for pepper and the other with a slit at the top for salt. Without that flash of intuition he might have battled for weeks to produce a design less simple, less straightforward to make, and less grounded in the technical tradition of the firm.

Moulded Plywood

Here again it is the industrial designer, rather than his technically minded counterpart, who has done most to develop the design potential of a new material. By mere chance, the moulding of plywood, perfected during the last war, attracted interest just as 'ergonomics'—which is concerned with the design of equipment in relation to the user—became a separate and important study. Early ergonomists did useful work on sitting posture to find out what shapes of chair best suited different purposes. This work strongly influenced a small number of designers, who saw in moulded plywood the chance to demonstrate practically their long-standing belief that a chair need not be upholstered to be comfortable.

Formerly the great majority of chairs had been constructed around a wooden frame. It now became possible to mould seat and back in one piece —a technique later transferred to glass fibre. It only remained to design and fix the legs. What designers have generally done is to connect two pairs of U-shaped legs with a crosspiece to which the seat is bonded with a highly efficient glue. The method works quite well in small-scale production, where each unit can be made with care, but it has had teething troubles in mass production of, say, restaurant or stacking chairs, owing to failure of the glue.

These examples suggest that, while new materials offer plenty of scope for new ideas which designers are eager to develop, they also pose a number of technical problems which can only be solved by co-operation between artistic and technical skills.

DESIGNING FOR NEW TECHNIQUES

The requirements of new techniques are no less exacting than those of new materials; but they are of a different kind. For a new technique, though it can be used to produce the same articles as before, often changes their shape and pattern, and sometimes their texture. Mechanization has posed this problem for over a hundred years, but there has always been a reluctance to face it squarely. The iconoclasm of rebel craftsmen and their friends was just as

unrealistic as the attempts of manufacturers to ape craft work by machine methods. By contrast the early railway and civil engineers were only too ready to come to terms with the implications of metals and steam power for design.

Machine-made Furniture

Some of these simple problems of mechanization have only recently been tackled in a systematic way. Let us take as an example the furniture industry where, with the growth of a mass market, mechanization has gradually taken root during this century. Although machine manufacture is associated in many minds with a fall in quality, the reverse is often true. Machines make far more accurate components and joints than can be made by hand and, given adequate glues, these can be assembled into sturdy and hard-wearing, yet inexpensive structures. But their very accuracy distinguishes them sharply from craftsmen's furniture; they are smooth and sleek, lacking the individuality given by rough joints and loosely fitting components. Moreover, machines cannot achieve the intricate carving or inlay work by which craftsmen have for centuries given an original and personal quality to their products. Certain decorative effects can be obtained with a router, or by assembling strips of finely machined wood into panels; but for the most part designers must relieve the hard outlines of machine-made cabinets with colour, careful choice of wood, overlapping joints and suitable legs and handles.

Features like these characterize the work of leading furniture designers in many countries today. Understandably enough, the lead has come from industrial designers and architects, rather than from engineers. But in most furniture factories and in millions of middle-class and working-class homes, the belief has persisted that machine-made furniture must ape traditional styles and *clichés*. A good deal of work has gone into the faithful reproduction of antique designs and the camouflage of machine-made furniture with would-be decorative but aesthetically mediocre strips. Where a break has been made with tradition it has often resulted in a needless confusion or exaggeration of outlines—for fear of facing the implications of a machine-made job.

In Britain, where this confusion is at least as widespread as in other countries, the issue came to a head during the last war, when the Government sought to meet a shortage of labour and materials with a scheme for 'utility' furniture, i.e., furniture simply designed for economical production at a controlled price. Several leading designers took part in the experiment, which laid bare the principles of designing for machine work, and thus made it easier for designers to develop a contemporary idiom of design after the war. But it so emphasized the plainness of machine-made pieces that the industry

at large and the general public reacted by leaning towards 'reproduction' or 'modernistic' furniture. Only after the Festival of Britain in 1951 did the 'contemporary' movement make a serious impact on taste.

But the problem has not yet been solved despite the emergence of a new design tradition and of distinctive ideas in Scandinavia, Italy and the U.S.A. It is easy even for good designers to make technical errors and, in striving for decorative effects, to produce furniture that is weak in structure. Moreover, a manufacturer may copy the *clichés* of a good design and build them into another design which is fundamentally unsound. The only long-term solution to the problem seems to be to face squarely the implications of mechanization.

Radio Manufacture

This example illustrates how conventions of design, formulated at the birth of a new invention, have to be changed as the invention develops and new techniques of manufacture are adopted.

A domestic radio set is both a functional instrument and a piece of furniture. As an instrument it needs encasing in such a way as to enhance, or at least not hinder, the acoustic value of the loud-speaker, and to protect the components from damage, while keeping them easily accessible for maintenance. As a decorative object it has to be styled like any other piece of furniture so that it may take its place in a living room.

So long as a radio receiver contained bulky valves in a three-dimensional wired assembly, and the quality of reproduction was limited by technical factors, the natural shape for the container was a box with a detachable back and curtained opening at the front to let out the sound. Recently, however, the advent of transistors and printed circuits has made it possible to assemble an amplifier in a flat box no bigger than a book, with the tuner running along the spine (only one tuning scale is necessary where VHF stations exist). For some time it has been known that 'high-fidelity' reproduction is best obtained through a baffle speaker which is housed separately from the set in a corner or along a wall. But the baffle speaker has never prospered, except among 'hi-fi' enthusiasts, because it is bulky and not easily incorporated in a furnishing scheme. Now, however, that pocket sets without speakers are technically feasible and the demand for good reproduction is growing, it seems logical to adapt the baffle speaker for large-scale use. Alternatively, an even newer type of reproduction—the electrostatic speaker, just emerging from the development stage—can be produced. It looks just like a panel, either fixed to the wall or standing on short legs. The radio of the future would seem therefore to be in two parts; a small slim box laid flat on a table or upright on a bookshelf, and a wall-panel or baffle speaker—a piece of furniture as carefully shaped as any other.

Mass Production and Standardization

One of the greatest design problems raised by machine manufacture and mass production is the ever-increasing degree of standardization required. Mass production thrives only when the number of competing models is reduced sufficiently to ensure a long run for all or most of them.

This requirement has three main implications for designers. First, their designs must have a wide appeal. Moreover, the article must stand up to hard wear, for the bigger the market, the more careless users it will contain.

Second, every effort should be made to contrive variety out of uniformity. For instance, a varied range of lighting fittings may be produced from a small number of standard components—say five kinds of shade, two socket covers, three ceiling suspensions and two wall brackets. Only a fraction of the several hundred possible combinations will be aesthetically attractive. A suitable number of these can be included in the catalogue and regularly assembled; the rest can be priced but only assembled on demand. If some of the catalogue entries prove unpopular, they can be replaced by others at short notice. Flexibility of this kind is fast becoming an important feature of modern design, especially of products that are built up from several components.

The third implication arises when interchangeability of parts is hardly feasible, and yet the design must prove attractive over a long period in order to sell in the economically required numbers. Designers must then harmonize the basic unalterable features with others which can be changed at intervals in order to give the product a new look. Motor-cars illustrate this practice. With notable exceptions like the German Volkswagen, the big motor-car manufacturers of Europe re-design their popular models every four to seven years, and re-style certain inexpensive features, such as radiator grilles and instrument panels, several times for each basic design, to meet the customers' demand for something new each year. The more features they can change or add, the more flexible is the design.

There is admittedly a school of thought which holds that frequent changes of style are unnecessary; if the car is technically good, it will sell widely for many years whether its styling is good or not. But this view is based on the assumption of wide technical differences between models; where these differences are narrow, the choice between models must depend largely on appearance and amenities. There is already ample evidence that the market for motor-cars is conscious of aesthetics and subject to changes of fashion. In a free market, therefore, some powerful manufacturers are certain to cater for these tastes, thus forcing many of their less powerful competitors to follow suit. The problem is not confined to motor-cars; it can arise wherever large and complex articles are mass-produced for a market affected by aesthetics and fashion.

None of the design problems of standardization are new; but as mass production extends to more and more processes and progresses towards automation, they are continually increasing in importance.

DESIGNING FOR VARIOUS FUNCTIONS

Craftsmen and design engineers have in common a tendency to specialize in one range of products or one set of techniques. Industrial designers, however, range much more freely. Wherever design engineers are unable to see all sides of a design problem, the management often brings in an industrial design consultant, even if he has little or no experience of the products and processes involved. The industrial designer is in a position akin to that of a professional writer asked to re-write a report on a subject of which he has no special knowledge. His very inexperience may help him to solve the design problems by a fresh approach; on the other hand, it may prevent him from seeing the full effects of his suggestions. Experience suggests that a good industrial designer can in time learn to work with specialized design engineers and help them to produce a design which is both technically and functionally sound and of good appearance. The engineer can teach the stylist what features of the design are essential to the proper functioning of the product; in return he can learn what gives the product its individuality and makes it pleasant to use and look at.

It is no accident that some of the most famous and interesting designs of our time have emerged from collaboration of this kind, mostly in the field of light engineering. Three examples are considered below—the typewriter, the sewing machine and the telephone—because the design of each involves a commonly encountered problem, that of putting a fine mechanism in a suitable case with matching accessory features.

The Typewriter

The Italian firm Olivetti, which has long been the pioneer of good typewriter design, considers that the design of so complex an article must be worked out as a unified concept. There are many technical requirements to be observed; the working components have to be given a certain strength and weight and placed in a certain relationship to each other; the keys should be light and comfortable to touch; the controls should be easily accessible for adjustment, and the type for cleaning; and the rest of the mechanism should be covered as fully as possible by a detachable case to preserve it from dust. For economic reasons the many components should be as simple as possible to make and assemble. Finally, for aesthetic reasons, the moulding of the case must both fit the mechanism and follow simple, pleasing lines; while the

external accessories—levers, knobs, keys and lettering on the type-face and keys—should be carefully designed to give the whole machine a harmonious appearance. It takes a good deal of patient experiment to fulfil these exacting conditions, but the result is a well designed typewriter with a certain individuality.

The Sewing Machine

The sewing machine is a much heavier object than the typewriter, and in the past sturdiness has been achieved by housing the mechanism in a cast-iron casing. As such a cover does not give easy access, the controls have usually been placed outside, giving the machine a somewhat higgledy-piggledy appearance.

Recently several European firms, notably Necchi of Italy and Helvetia of Switzerland, have attempted to re-design their machines, using either a cast-iron casing or an open structure panelled with fixed and detachable plates. The idea is to build into the casing as many parts as possible, including the guide wheel and the electric motor, and to group the controls neatly for convenient use. This job requires just as close collaboration between technical and aesthetic specialists as the design of a typewriter, and the two case-histories are similar in many respects. Necchi's practice is to let its design engineers construct a working model that is technically sound before bringing in an industrial designer. The latter then collaborates with the rest of the team until a final design, which both leaves the technical qualities unimpaired and satisfies the sales department, has been agreed upon. The outcome is a sewing machine with individuality and good appearance.

The Telephone

The same collaboration between members of a design team is evident in recent work on telephones. But here the design problem is more complex. Technical considerations dictate the distance and angle between receiver and transmitter, and these two components have been placed in one part of the instrument—the handset—ever since this has been technically possible. The remaining components are usually housed beneath a case shaped rather like a cheese-dish; the dial is placed on the oblique side of the case at an angle of about 45 degrees, so that the numbers are visible to the user while the base remains steady during dialling.

Post-war models, notably the American Bell and the new British Siemens-Edison-Swan, have refined this basic design to the limit. Yet it has serious weaknesses in use. The receiver is apt to fall off the cradle hooks when the instrument is being carried about, and dialling is only simple when the base rests on a table or desk. Many users are not inconvenienced by this, but

there is no reason why telephones should not be more portable and be used comfortably in an armchair or in bed.

The Swedish firm L. M. Ericsson, which pioneered the handset over sixty years ago, has been working on this problem since the end of the last war. It has produced a new model in which a thermoplastics handset, shaped somewhat like a leg of mutton and weighing only 14 ounces, contains all parts of the mechanism except the buzzer and the capacitor. The dial is set in the base of the handset and the user can lift the instrument from any resting place (in doing so he switches on the mechanism), turn it over with an easy sideways movement of the wrist and dial with the other hand, using his lap for support if he wishes.

To make such a novel instrument possible, design engineers laboured for years to reduce each part in size and make it of the lightest possible material. At the same time the plastics case had to be carefully shaped and made decorative for the home, and the design of the dial and its lettering had to be carefully studied. It is too early to judge whether this type of design will displace the more conventional one; but it seems the most logical arrangement yet presented and is bound to influence the shape of future telephones.

The Motor-car

These three examples show how certain engineering products, if well thought out and designed, can become the modern equivalent of the craftsman's masterpiece. Many other cases too could be quoted; but there are also important examples where problems of function are not properly faced.

The motor-car industry provides a good instance, since the fashion element in car design sometimes detracts from efficiency in use. Preoccupation with length makes cars much less manoeuvrable in traffic and on mountain roads. Boot space is often extended at the expense of passengers' comfort, so as to give balance to the side elevation. Above all, many current designs, though cheap to produce, are costly to repair. Before the last war a good deal of damage by impact was confined to running boards and detachable wings. Nowadays it is usual to incorporate wings in body pressings, and the running board has disappeared in the interests of sleekness; thus a motor-scooter, driven obliquely into the side of a car, can cause three large panels to be removed, beaten and re-sprayed.

Designs such as these are a matter of commercial policy and not primarily the fault of designers, many of whom would like to reconsider the principles of car design in the light of new technical advances. This same problem arises in many fields other than the automobile industry.

ORGANIZING THE DESIGN FUNCTION

There are many manufacturers to whom design means little more than draughtsmanship, and who hand over the responsibility for designing to someone with little more than an intuitive understanding of what the market will take. A growing number, however, treat design much more seriously and once they do so they must consider what changes in management it implies.

They soon find that there is no half-way house between neglecting design and giving it a favoured place in the hierarchy of management; their first task therefore is to allocate responsibility for design policy. It is widely agreed among the more experienced firms that control must lie at board level, since only thus can interdepartmental differences be ironed out quickly and smoothly. Usually one of the directors is made responsible for initiating policy and for defending it at board meetings.

Harnessing the Design Team

The second big task is to harmonize the technical and aesthetic elements in the design team, which may vary from a formal department in a big engineering firm to a loose *ad hoc* association in a small craft-based firm. But each case has to be worked out individually and success depends very much on personalities.

One of the most difficult decisions for the design director is whether to employ industrial designers on the staff or to call in consultants to work with the staff engineers. There is no rule of thumb for this decision; each method has its merits and disadvantages. The staff designer gradually acquires specialist knowledge and absorbs the traditions of the firm, but he can easily become stale unless he makes a point of getting out of the factory and coming into contact with new ideas. The consultant, on the other hand, may be relied upon to be up to date, but he cannot always grasp a specialized design problem as thoroughly as a staff designer. By and large, it is more difficult to integrate a consultant into the design team, since he has few opportunities for breaking down suspicion and resistance. But most good consultants, notably the increasing number who specialize in engineering products, find that tact and patience can overcome this disadvantage by the completion of the second or third job.

A third task is to determine the stage at which the man responsible for styling should be brought in. In the craft-based industries, he must be on the spot from the beginning, but in an engineering factory there is much to be said for solving the basic technical problems first, and presenting the designer with an already working mechanism. It is a growing practice in engineering companies to bring all interested specialists into the early discussions at which

the purpose and characteristics of the proposed design are clearly defined; to leave the design engineers to devise a mechanical structure within agreed terms of reference; and only then to consider at length the question of styling.

Relating Design to Other Departments

A fourth problem is how to keep good relations between the design department and departments which have to make, sell and advertise the product. A good designer and a good production engineer have much in common; they both want designs that are simple and inexpensive to make—unless, of course, they are catering for a small luxury market. They both want to utilize existing equipment as far and as fully as possible. They are both eager to reap the advantages of standardization and to design within the technical limits of materials and methods. Even so, serious divergencies do arise. A designer may exceed the bounds of technical possibilities or set needlessly complicated problems of tooling; a production engineer, on the other hand, may not realize at first the full implications of a revolutionary design, and may see in it difficulties that do not exist. Problems like these can only be overcome by close consultation at all stages in designing.

With sales and publicity the problems are different. These departments are interested above all in a product that has sales appeal and a standard of performance that justifies their sales talk. They are thus inclined to look carefully at each new design in case it fails on either count. Problems of performance need not arise if testing has been thorough. But problems of sales appeal are often extremely baffling, especially in products affected by changes of fashion; and the larger the production, the more serious they become, since the design must satisfy more people.

In essence the question is 'Does good design mean good business?' Designers invariably answer that it does, provided that it is backed by good salesmanship. Salesmen have a natural tendency to say that it does not, whenever they see bad design doing very well. But both sides are apt to oversimplify the problem. There are obviously many good designs which are too expensive or too advanced aesthetically for the class of market for which they are intended. Also where fashion rules, the unfashionable has limited appeal whatever its virtues; the 'knife-edge' style of motor-car, though very dignified, made little headway when it was introduced just after the last war, and soon disappeared.

At the same time the existence of a good market for current designs is no excuse for resisting change. For one thing, markets are always in transition, and what sells today may prove unsaleable tomorrow. Again, even though the old designs are doing well, the new one may do even better. Also, every success scored with a new design helps to build up a good reputation for the firm, and this is a long-term investment. Modern experience suggests that the

buying public is a good deal less conservative than many manufacturers and retailers believe it to be; it can be quickly weaned from one style of design to another. Producers must make up their minds whether to cater for the market as it seems to be, or whether, on the basis of careful consumer research, to lead it by intelligent anticipation. Firms that take design seriously eventually decide on the second course; but sales managers often prefer the first, and can only slowly adjust their approach to the second.

A fifth problem is that firms, especially when they become big, do not impinge on the public solely through their products. They have office and factory buildings in different parts of the country; they send out vast quantities of advertising literature, posters, forms, letters and other printed matter; they use trade marks to build up their names; they may sell their products in separately produced packs. All these activities involve designing of one sort or another, and this must be done within the framework of their design policy, since good products go incongruously with bad packs, squalid offices or garish delivery vans. This trend strengthens the case for putting responsibility for design at a very high level, since it requires not only co-operation between departments but the evolution of a distinctive house-style for each firm.

Training Designers

Along with these specific questions of organization of design inside the firm goes the wider problem of how to train designers. Because design is a new profession, arrangements for recruitment and training are far from systematic. A design engineer usually receives a purely technical training with no aesthetic bias; if he develops a feeling for form, pattern, texture or colour, it is usually due to his own initiative or to that of a gifted teacher. The industrial designer however, is a product of schools of art and crafts, and these vary a great deal in their contacts with industry and their knowledge of what industry requires of designers. In the past their students have passed into the craft-based industries, or into consultant firms where they are required to do a variety of jobs, including much display design.

In most areas neither type of training produces enough designers of the kind needed by modern industry. Young people leaving art schools find staff jobs in industry bleak, except when they deal with attractive products such as furniture and pottery or are employed by very enlightened firms. They are often impatient with restrictions on their freedom to create and do not quickly learn the technical limitations of the processes with which they are concerned. By contrast, design engineers do not often possess the imagination and sense of proportion that are vital to good design.

In order to solve this dilemma the leading training schools of many countries are trying to combine aesthetic and practical education in one course

and to give students as much experience in industry as possible. A few of them are trying out 'sandwich' courses in which a student has, say, three months' academic instruction and practical training in one group of subjects, then takes three months' employment in industry, then goes back to college for instruction in a new group of subjects, and so on. This kind of training, accompanied by a trend towards specialization, is inevitably lengthening courses. In a number of countries, designers have formed professional associations to establish standards and codes of conduct comparable to those that have long existed for architecture. Entry to these associations is usually conditional on reaching a certain level of attainment; it is therefore as much a professional qualification as membership of engineering associations.

All these developments are making it easier to recruit young designers for specialized training within the firm, than to wait for them to mature and prove their ability in consultant or other outside work. But generally speaking, there is a kind of vicious circle; industry is slow to recruit designers because it knows that the number of good designers is small and that bad ones are a waste of money; while schools will not start intensive courses in design, and students will not follow them, if there are not enough interesting jobs for them in industry. However, once the circle is broken—and in a few countries it almost is—design, like architecture, should prove an attractive profession to any youngster whose mind works in visual images rather than in words or figures.

Looking Ahead

A final problem of organization is how to arrange for continued experiment in design in order to keep pace both with advances in technology and the changes in consumer needs. As has already been mentioned, firms that think out their design problems seriously find that they have to anticipate and not merely reflect public demand. But a really forward-looking firm goes further and has designers working at least part of their time on *avant-garde* ideas. These may never leave the drawing board, but on the other hand they may go into small-scale production or form a tiny portion of a large and varied range of mass-produced goods. In most large cities there is a small but influential group of discerning consumers who seek advanced designs and who are ready to support by their custom a few firms which concentrate their resources on extending the frontiers of taste. This untypical market is a useful testing ground for new materials and techniques, and for design ideas that have not yet proved themselves practical in use. It also opens a shop window for new ideas and enables manufacturers to see which of them may have attractions for the mass market.

Many manufacturers are finding that experimental work is one useful way of keeping a staff designer alert and happy. It also contributes to the long-

term education of technicians and managers in the principles of designing for machine manufacture.

CONCLUSION

Mechanization has completely changed the task of designing and raised problems of adaptation which industry has only recently begun to solve. Until recently experience of these matters was confined to a few pioneer firms. Now, however, this experience is widening considerably, and an increasing number of companies are eager to profit from it. What lessons can be learnt from firms like Necchi and Olivetti, Renault and Ford, and the instrument makers of Switzerland and Germany?

The first lesson is that a modern firm can no more treat design as an unfortunate necessity than can a craft workshop. The acknowledged leaders of modern design do everything to ensure that each new design is as near right as possible before it goes into production; they then study it carefully in use and improve it if need be when it comes up for re-designing. They consider that the success of a design depends on close co-operation between the design, research, development, production and commercial departments, and accordingly they place the ultimate responsibility for it at board level.

It is clear to those who have personal experience of the pioneer firms that the design 'atmosphere' of a factory can vary enormously. In some, the attitude to design springs from the influence of a gifted and imaginative founder. His inspiration gives the firm a lasting individuality which pervades everything from the board to the lower levels of management. The individuality is not usually confined to design; it extends to spheres like architecture, town planning and patronage of the fine arts. These firms seem to be the true successors of the wealthy individuals who patronized the arts and crafts so successfully before the machine age; but they are few and will probably remain few.

The more usual experience is that a few members of a board convince their colleagues of the need for a constructive design policy and gradually make the management conscious of the satisfaction that can be derived from dealing in goods of high quality and prestige. Their attitude to design may be more mundane than that of the more inspired firms, but it can produce equally good results because it too implies a creative approach.

A second lesson to be learned from firms successful in design is that there is no short cut to success where mass production conditions obtain. Each design may take months or years to perfect; and the more complex the product and the processes by which it is produced, the more thought must go into its creation.

A third lesson is the supreme importance of finding the right qualities in

a designer or design team. It is not enough to have engineers who can build a first-rate mechanism if they are unable to see it from the user's point of view. Likewise, it is not enough for an industrial designer to make a product that is a delight to behold if the mechanism is unsatisfactory. The Italians often speak of an 'engineer-artist' as being the ideal person to take charge of designing; but it is doubtful if such a type could be found in large numbers. Pioneer firms pay very close attention to recruitment and training, and constantly seek to overcome the technical deficiencies of the industrial designer and to develop the aesthetic potential of their engineers, so that both can work harmoniously together. They generally agree that outlooks cannot be broadened sufficiently either within four walls or in spare time; design staff must be able to spend official time in making external contacts, visiting exhibitions, watching the progress of competitors designs and discussing common problems with colleagues.

A fourth and final lesson is that not all the problems raised by mechanization have yet been solved; much remains to be done, especially in the decoration of useful objects. This task, which was performed so well by traditional craftsmen, does not yet lend itself easily to mechanization. Objects in stainless steel and some plastics are best left undecorated, but wood, pottery, glass and the lighter metals often benefit from surface treatment. Even today much decoration has to be applied by hand, or by partly mechanized methods; and where this is impracticable on economic or aesthetic grounds, as in the case of wood and metal cabinets, designers have concentrated mainly on colour effects or on careful detailing of features such as knobs and handles. Only in the textile trades have they been able to let their fancy run riot—and then usually as commercial artists rather than industrial designers.

It is doubtful whether this problem will ever be satisfactorily solved, partly because mass production goes with simplification, and partly because there are not many forms of decoration that lend themselves naturally to machine work. The craftsman expressed his individuality through adornment; but the industrial designer must express his through the exacting medium of the machine. It was possibly nostalgia for the craft decoration of bygone centuries that created a vogue for pointless or ill-conceived decoration in machine-made products, and prevented the adaptation of sound principles of design to the machine age.